



Technical Report CHL-99-19  
September 1999

**US Army Corps  
of Engineers**

Engineer Research and  
Development Center

# **DMS: Diagnostic Modeling System**

## **Report 2**

### **Reduction of Sediment Shoaling of the Entrance Channel at East Pass, Florida**

*by Mark S. Gosselin, Kenneth R. Craig, R. Bruce Taylor,  
Taylor Engineering, Inc.*

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Prepared for Headquarters, U.S. Army Corps of Engineers

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by Mark S. Gosselin, Kenneth R. Craig, R. Bruce Taylor

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Final report

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Prepared for U.S. Army Corps of Engineers  
Washington, DC 20314-1000  
Monitored by Coastal and Hydraulics Laboratory  
U.S. Army Engineer Research and Development Center  
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

#### **Engineer Research and Development Center Cataloging-in-Publication Data**

Gosselin, Mark S.

DMS : Diagnostic Modeling System. Report 2, Reduction of sediment shoaling of the entrance channel at East Pass, Florida / by Mark S. Gosselin, Kenneth R. Craig, R. Bruce Taylor ; prepared for U.S. Army Corps of Engineers ; monitored by Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center.

63 p. : ill. ; 28 cm. — (Technical report ; CHL-99-19 rept.2)

Includes bibliographic references.

1. DMS (Computer system) 2. East Pass Inlet (Fla.) 3. Inlets — Florida. 4. Dredging — Florida — East Pass. 5. Sedimentation and deposition — Florida — East Pass — Computer simulation. I. Craig, Kenneth R. II. Taylor, R. Bruce. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Research and Development Center. V. Coastal and Hydraulics Laboratory (U.S.) VI. Title. VII. Title: Reduction of sediment shoaling of the entrance channel of East Pass, Florida. VIII. Series: Technical report CHL ; 99-19 rept.2.

TA7 W34 no.CHL-99-19 rept.2

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# Preface

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The study described in this report was performed under the Diagnostic Modeling System (DMS) Work Unit of the Coastal Sedimentation and Dredging Program administered by the Headquarters, U.S. Army Corps of Engineers (HQUSACE). Research and Development activities of the DMS are being conducted at the U.S. Army Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS. HQUSACE Program Monitors are Messrs. Earl Eiker, Charles B. Chesnutt, and Barry W. Holiday.

Work was performed by Dr. Mark S. Gosselin, Mr. Kenneth R. Craig, and Dr. R. Bruce Taylor of Taylor Engineering, Inc., Jacksonville, Florida. The Contract Monitor and Principal Investigator of the DMS work unit was Dr. Nicholas C. Kraus, Coastal Sediments and Engineering Division (CSED), CHL. Dr. Kraus provided direction for and technical review of this report.

Work at CHL was performed under the general supervision of Dr. James R. Houston, Director, and the administrative supervision of Mr. Thomas W. Richardson, Chief, CSED, CHL.

At the time of publication of this report, Dr. Lewis E. Link was Acting Director of ERDC, and COL Robin R. Cababa, EN, was Commander.

# Conversion Factors, Non-SI to SI Units of Measurement

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Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
square miles	2.589998	square kilometers

# 1 Background and Problem Statement

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This report documents a joint case study conducted by the U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL) and Taylor Engineering, Inc., to assess the functioning of the Diagnostic Modeling System (DMS). In this case study, shoaling patterns at a Federal waterway at East Pass, Florida, provide an evaluation site for trial application of the DMS. The shoaling at the entrance channel at East Pass Inlet serves as the second exercise and evaluation of the DMS concept (for the first application, see Kraus, Mark, and Sarruff (In preparation)).

## Background

The DMS is being developed under the Coastal Sedimentation and Dredging Program administered by the U.S. Army Corps of Engineers (USACE). The DMS is intended to provide the USACE with a rapid, yet reliable, capability to develop and evaluate navigation channel operations and maintenance (O&M) alternatives based on limited information on the hydrodynamic and sediment-transport conditions at a site.

The DMS gives a rapid evaluation or diagnosis of a problem shoaling area and provides guidance for determining possible solutions. The economic lever underlying the DMS concept is that a low-level analysis, possibly supplemented by a modest numerical modeling effort, can yield substantial cost savings without interrupting ongoing O&M activities and schedule. That is, the DMS is intended to provide feasible alternatives for reducing O&M costs within the dredging cycle of the subject project. The application time and effort in applying the DMS are relative to the maintenance time of the project.

Taylor Engineering is currently developing the State-mandated inlet management plan for East Pass in cooperation with the City of Destin, Okaloosa County; the Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems; and the U.S. Army Engineer District, Mobile. The Mobile District identified a study site in East Pass, Florida, where dredged volume is increasing and navigation is becoming more difficult. This report describes the application of a DMS approach to East Pass.

This chapter begins by presenting an overview of the DMS methodology and follows with a description of the case study area. This description includes a short history of the area, a discussion of the physical processes, and a listing of

the dredging history. This information is intended to facilitate discussion of the application of the DMS in ensuing chapters. The chapter concludes with the problem statement and the objectives and procedures of the investigation.

## DMS – overview

The DMS will provide a quick and concise capability to identify, categorize, and evaluate navigation channel sediment-deposition hot spots for correction. The DMS will incorporate established public-domain coastal hydrodynamic models to be applied, as necessary, in combination with a suite of analytical tools and procedures. The strategy behind this concept is to develop an experience-based methodology for treatment of shoaling problems. The tools included in the DMS will help engineers identify problem areas of shoaling, characterize the causes of these problems, and develop practical, cost-effective solutions.

The DMS methodology relies upon the use of established public-domain coastal hydrodynamic models, typically developed by the USACE, in combination with a suite of engineering analyses and procedures founded upon principles of fluid dynamics and sediment transport. For this reason, the methodology is referred to as the *Diagnostic Modeling System*, or DMS. The DMS is intended to be a common-sense diagnostic tool that is easily applied by engineers directly engaged in the planning, design, and maintenance of navigation projects and waterways to do the following:

- a. Identify potential problem areas of shoaling.
- b. Identify characteristic causes of these problems.
- c. Assist with the development of practical engineering solutions that will decrease the cost of project maintenance by enhancing project performance.

As such, the DMS is not intended to provide the level of detailed information required for final design or in-depth study. Rather, it is intended to quickly diagnose the problem, categorize it according to its key characteristics, and identify corrective actions that can be taken within project authorization. The diagnostic procedure should be capable of completion within a time span shorter than the project dredging cycle.

This investigation makes no effort to develop or advance numerical modeling techniques for the evaluation of sediment deposition. The literature contains numerous examples of the considerable effort expended in this arena. Rather, the DMS will combine established hydrodynamic modeling techniques with specialized output formats and back-end sediment-transport analytical procedures to arrive at an effective diagnostic methodology to quickly characterize and evaluate sediment-deposition behavior. Several coastal hydrodynamic models can provide reliable information of sufficient accuracy to perform the work envisioned. The heart of the research lies in the application of such model to obtain the type and format of the information required, the engineering experience gained through observation, and the development and application of concise, easy-to-use analytical procedures to systematically diagnose characteristic sediment-deposition problems.

As envisioned, the DMS comprises three components: the DMS-Data Manager, the DMS-Manual, and the DMS-Analytical Toolbox. The DMS-Data

Manager, a GIS-based computer program, allows the user to organize and view all the relevant information within a project area. Examples of the data kept in the DMS-Data Manager include digitized bathymetries, aerial photographs, GIS coverages, and shoaling history. This component gives "one-stop" access to all graphical and numerical information associated with a maintained channel.

The DMS-Manual is a reference document containing diagrams and example photographs of different shoal categories. This "field guide" to shoaling problems helps identify the types of shoals by giving the user comparable examples. In addition to providing diagrams and examples, the DMS-Manual also gives descriptions of the sediment shoaling and shoals, and the mechanisms that create these features.

The DMS-Analytical Toolbox is a suite of analytical tools and recommendations in graphical formats for quick diagnosis of shoaling problems and investigation of possible solutions. This toolbox includes a collection of computer software (e.g., hydrodynamic models, wave refraction/diffraction models) and analytical models (e.g., sediment-transport equations, wind-generated wave models). In addition, the toolbox contains recommended output formats from the models. By standardizing output formats, mechanisms that contribute to shoaling will become easier to identify. The use of standardized output formats facilitates the building of an experience base with which to compare future shoaling investigations. Applied in parallel, these three components provide for rapid and systematic assessment of shoaling hot spots. Application of each component to the shoaling hot spots at East Pass, Florida, is the focus of the present study.

### **East Pass – history**

Application of the DMS requires familiarization with the study area. This may be accomplished through a literature search, site visits, and discussion with persons familiar with the area. This process discovers and assembles the available data for the study area. The data will subsequently become input for the DMS-Data Manager. This section familiarizes the reader with the study area by providing a brief history of the pass and of the work performed there.

East Pass is the only direct tidal link between the Gulf of Mexico and Choctawhatchee Bay. Measuring approximately 4,000 ft long and 1,000 ft across between the tips of the jetties, East Pass is located about 45 miles east of Pensacola and 50 miles northwest of Panama City. Figure 1 shows the configuration of East Pass and adjacent areas. Situated at the coordinates 30°23'N and 86°31'W, East Pass is positioned between Santa Rosa Island to the west and Moreno Point to the east. At 45 miles, Santa Rosa Island, the second longest barrier island on the Gulf Coast, spans from East Pass on the east to Pensacola Pass on the west. Averaging between 1,000 and 1,500 ft in width, this long, narrow island shelters Santa Rosa Sound located directly north. Santa Rosa Sound is a natural waterway connecting Choctawhatchee and Pensacola Bay. The easternmost 4 miles of the island comprise Eglin Air Force Base and, for the most part, remain undeveloped. Moreno Point is the western edge of a headland separating Choctawhatchee Bay from the Gulf of Mexico. The City of Destin is located on Moreno Point north of the inlet. On the east side of the pass near the jetties is a sand spit, known as Norriego Point, that formed in 1935. This spit and

the beach directly east is known as Holiday Isle. The spit has been developed with roads, canals, and condominiums since the 1970s.

Choctawhatchee Bay, landlocked except for East Pass and Santa Rosa Sound, has an area of 122 square miles, is approximately 30 miles long, and averages 4 miles in width north to south. The Garniers, Boggy, Rocky, and La Grange Bayous to the north and the Choctawhatchee River to the east

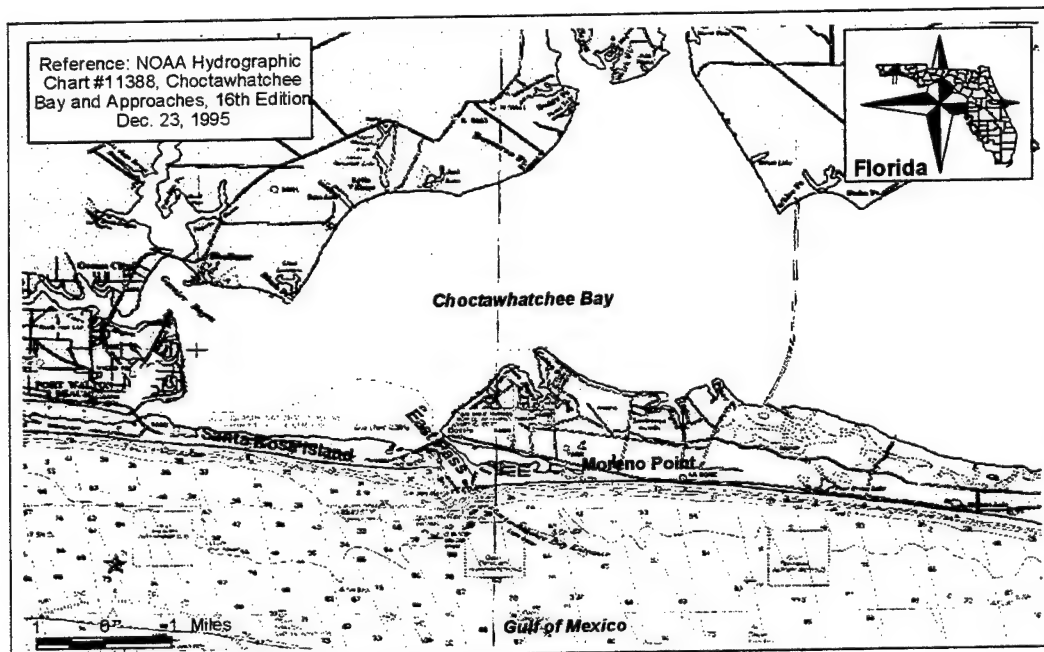


Figure 1. Location map for the study site and the Gulf of Mexico

provide freshwater influx into the bay. The Intracoastal Waterway connects to the eastern edge of the bay, and Santa Rosa Sound attaches at the southwest edge. East Pass links the Gulf of Mexico to the bay at the bay's southwest edge.

The stability of East Pass is of great significance to local interests. Traffic through the inlet includes charter vessels, a fishing fleet, recreational craft, some freight traffic, and military vessels. The tourism and real estate industries also have a vested interest in the condition of the inlet, specifically, the inlet's eastern side consisting of Holiday Isle and Norriego Point.

A review of East Pass history and the surrounding area gives the natural behavior of the inlet as well as an account of the inlet's response to previous stabilization attempts. As the only inlet for 100 miles on this stretch of the Florida panhandle, East Pass has provided a passageway for vessels since the early 1800s. The first hydrographic map of the area, made by John Williams in 1827, indicates that Moreno Point occupied much the same position as it does today (Morang 1992). In addition, the location of a flood shoal and the northern terminus of the pass was also situated at its current position adjacent to Moreno Point. The southern terminus, however, has changed significantly. The 1827 inlet mouth entered the Gulf of Mexico 1.5 miles east of its current position. During this time, the inlet had a more northwest to southeast orientation. The brackish pond 0.5 miles east of the 1827 inlet mouth implies that in the past, the

inlet entered the Gulf at least 2 miles from its current location. From 1871 to 1929, East Pass migrated approximately 2,500 ft westward. In addition, progressive erosion occurred at Moreno Point. These two mechanisms effectively bent the channel and created a much less efficient hydraulic state.

In April 1928, severe storms and high tides caused a breach in a low narrow portion of Santa Rosa Island at about the location of the present inlet. This breach soon shoaled and the original inlet remained open. In 1929, another heavy rainstorm flooded the Choctawhatchee Bay. High-water marks indicated that water levels had risen to as much as 5.4 ft above mean low water (mlw). The local inhabitants dug a pilot channel along the 1928 breach to allow the high waters of the bay to rush into the Gulf (U.S. Engineer Office 1939). Because the new channel provided a more direct route to the Gulf, it became more hydraulically efficient. As such, it soon captured the tidal flow in and out of the bay and remained open.

Following the breach, changes in the shoreline occurred rapidly. By 1935, the new inlet had grown to 2,500 ft wide. The old inlet soon shoaled and, by 1938, completely closed. The east side of the new inlet had receded 500 ft eastward from its original 1929 position (U.S. Engineer Office 1939). In addition, by 1931, a sand spit (later named Norriego Point) had formed along the eastern edge of the inlet and stretched northward to a point within 500 ft of Moreno Point. The reduced depth between the spit and the mainland required dredging approximately 20,000 cu yd of material to create a channel (hereafter referred to as Old Pass) 6 by 100 ft to connect Old Pass Lagoon to East Pass. This was the first in a long history of dredging projects at East Pass.

Navigation through the newly formed East Pass proved perilous for small vessels. The crescentic bar at the outermost edge of the ebb-tidal shoal had a history of shifting significantly during storms. In addition, Government acquisition of Valpariso Airport, which would later become Eglin Air Force Base, meant that channels through the pass required modification and maintenance to allow passage of military vessels. Before 1945, dredging occurred periodically to maintain a 6- by 100-ft channel through East Pass. In June 1945, the Air Force paid the USACE to dredge a channel 12 ft deep and 180 ft wide through East Pass (U.S. Congress, House 1950). In 1951, Congress authorized the dredging of a 6- by 100-ft channel extending from the east end of the U.S. Highway 98 bridge through Old Pass into Old Pass Lagoon. These channel dimensions continue to the present. The rapidly shoaling East Pass channel quickly returns to about 7 or 8 ft deep at mlw. Consequently, maintenance dredging must be continuously scheduled.

To improve the inlet's navigational safety and to reduce annual maintenance costs, the 1963 USACE survey report recommended constructing jetties to protect the entrance to the Gulf of Mexico. The report also recommended a substantial amount of dredging to coincide with jetty construction. The total estimated cost of the project was \$1.87 million. Jetty construction and dredging began in December 1967 and ended in January 1969. The jetties featured a converging design constructed to the -6-ft mlw contour that ends with an opening 1,000 ft across (Mobile District 1967). A 1,000-ft weir was placed in the west jetty near the landward end to allow littoral drift to enter a deposition basin on the opposite (east) side of the weir. Within the shelter of the jetties, a dredge

could pump sand to renourish the downdrift beach. A regular dredging schedule would minimize the interruption of littoral drift by the jetties/inlet and the accumulation of sediment at the updrift side. A deposition basin was dredged to provide a 2-year supply of sediment, an estimated volume of 300,000 cu yd.

Between April and June 1969, a few months after completion of the jetties, a 100-ft section of the weir collapsed. The collapse caused a deep trough to be scoured away through the breach. As a temporary remedy, 67,000 cu yd of sand was pumped from the deposition basin onto the jetty. This sand temporarily blocked the entire weir; however, all the sediment had eroded by March the following year. The weir was permanently repaired in September 1970. Since its construction, the deposition basin was dredged only twice, in 1970 and 1972. Differing opinions as to the source of the sediment filling the basin and the direction of longshore drift caused the end of maintenance dredging of the deposition basin. In addition, at this time, concern grew over the continuing erosion of Norriego Point and the western tip of Moreno Point. Popular opinion held that the weir allowed large waves to pass through and erode the point. Under pressure by local interests, the USACE recommended weir closure in its 1983 *Reconnaissance Report, East Pass Channel, Destin, Florida* (Mobile District 1983). In 1985, the USACE permanently closed the weir by covering it with a rubble-mound trunk section identical to that placed on the rest of the jetty.

By April 1977, erosion of the East Pass eastern shoreline (Norriego Point) required immediate attention. A report on shoreline improvement and dune stabilization was submitted to the USACE South Atlantic Division Engineer. This report recommended the construction of a groin field consisting of six structures located at the northern end of Norriego Point (Mobile District 1977). It claimed that wind-generated waves traveling through the mouth of the inlet caused the most severe erosion along the point. The authors specifically did not identify the weir as playing a role in the erosion. This recommendation was rejected. However, the continued easterly channel migration had eroded the eastern shoreline to a point where the east jetty was in danger of being flanked. General inlet maintenance occurred in 1977 with the construction of a 300-ft rubble-mound spur that attached at a right angle to the landward end of the east jetty. The purpose of the spur was to divert flow away from the landward terminus of the jetty. By the 1980s, scour holes had formed at the tip of the spur as well as at the tip of the west jetty (Lillicrop and Hughes 1993). Until 1993, maintenance of the spur jetty had been limited to the placement of dredge material, riprap stone, and concrete rubble in the scour hole. More extensive repairs were completed in 1994.

On 4 October 1995, Hurricane Opal made landfall at 1700 Central Daylight Time. The eye of this Category III (at landfall) hurricane passed near the town of Mary Ester located approximately 12 miles west of East Pass. Opal generated winds with gusts in excess of 150 mph and produced a storm surge reaching 14.6 ft above mhw. Following the storm, the USACE deployed their Scanning Hydrographic Operational Airborne Laser System (SHOALS) to assess Opal's damage at East Pass. Morang, Irish, and Pope (1996) separated storm damage into two categories: subaerial changes caused by the storm surge during the height of the storm, and subaqueous changes caused by the draining of the flooded Choctawhatchee Bay.

Subaerial changes included the following:

- a. The overwashing of Santa Rosa Island and the landward side of the west jetty, an action that led to the creation of a large depositional fan in the lee of the island and the accumulation of sand in the area previously occupied by the deposition basin.
- b. The breaching of Norriego Point with deposition of sediment in Old Pass Lagoon.
- c. The overwashing of the beach east of the east jetty, an action that flattened dunes and carried sediment into the area eroded near the spur jetty and further into the thalweg of the channel.
- d. Minor damage to the jetties involving the settling of the capstones.

Morphological subaqueous changes associated with the ebb jet and post-recovery included the following:

- a. The formation of a contraction-induced scour hole at the inlet throat between the jetties.
- b. The westward movement of the thalweg away from the shoreline and subsequent channel straightening.
- c. The further deepening of the scour holes at the tips of the west jetty and spur jetty.

Notably, Hurricane Opal caused no significant change in the ebb shoal's growth pattern. In contrast to this assessment, the local USACE office reported no apparent deepening of the scour holes as a result of Hurricane Opal. More information concerning the damage caused by Hurricane Opal is contained in Leadon, Nguyen, and Clark (1998) and Leadon (1996).

The preceding account of the history of the inlet has accomplished three goals. First, it pointed out the need for the DMS system. Considerable money and effort have been expended at East Pass to improve the navigational safety of the Federally maintained channel. The use of the DMS at certain stages in this channel's history may have pointed to better solutions than the ones attempted (e.g., the weir jetty). Second, it validated the choice of East Pass — a location where maintenance efforts have expended considerable time and money — an appropriate demonstration site for application of the DMS methodology. Finally, it has familiarized the reader with the study area to facilitate later discussion.

### **East Pass – physical processes**

Knowledge of the physical processes in the study area also aids in the diagnosis of shoaling problems. Notably, the DMS intends to address the mechanisms that cause shoaling rather than simply treat the shoaling itself. In this regard, application of the DMS is a proactive rather than the traditional reactive approach to addressing shoaling. As such, knowledge of the channel's physical processes that cause the shoaling is essential in finding a defensible and successful shoaling mitigation method. This section characterizes the physical processes at East Pass through a literature search.

To comprehend an inlet's tidal hydrodynamics, one must document not only the tidal ranges and their consequences but also the influences of bay geometry,

freshwater influx, wind forcing wave setup, and storm surge. Several sources (e.g., Wright and Sonu 1975 and Mobile District 1986) have reported a diurnal astronomical tide in East Pass with a mean range of 0.6 ft and a maximum spring tidal range of 0.9 ft.

In addition to these sources, the USACE has documented the results of several tide-monitoring efforts including measurements from 1938, 1983-1984, and 1987. These measurements show that the bay's geometry plays a role in the tidal amplitude and phase within the bay as compared with tidal records in the Gulf. The Mobile District report *Monitoring Program, East Pass Channel* (1986) documents that measured tidal ranges in Choctawhatchee Bay corresponding to 0.5 and 1.5 ft have associated tidal ranges in the Gulf of Mexico of 1.2 and 2.5 ft. These values respectively translate to a 40- to 60-percent reduction in amplitude between the bay and the Gulf. In addition, an estimated 5.7-hr phase difference occurs between the tidal elevation in the bay and in the Gulf. These differences are mostly attributable to the bay's large surface area (~122 square miles) and particular channelization. The 1939 U.S. Engineer Office report *Study of East Pass Channel, Choctawhatchee Bay, Florida* offers the most comprehensive analysis of this phenomenon. The report attributes the reduced amplitude to the large hydraulic resistance through East Pass (mainly a function of the flood-tidal shoal). The report also attributes the phase lag to that part of the bay's tidal inflow that travels along the much longer route to Pensacola Bay via Santa Rosa Sound.

The two known sources of tidal current measurements are the 1939 U.S. Engineer Office report and the 1992 USACE study (Morang 1992). The 1939 report presents the results of float studies performed at various times during the tidal cycle. In the main body of the text, the authors report measured maximum flood velocities of 1.97 and 4.37 ft/sec (two different field measurements) and a maximum ebb velocity of 3.39 ft/sec. In a table found in the report, however, the reported maximum flood and ebb velocities through East Pass — 1.5 and 1.7 ft/sec — are presumably based on measurements of the maximum discharges through the inlet and a representative cross-sectional area. Morang (1992) reports the results from field investigations in 1983, 1984, and 1987. Maximum currents measured during flood tide across the inlet were between 4.5 to 5.0 ft/sec at the surface and 2.5 to 3.0 ft/sec at the bottom (measured at a distance of 0.2 times the water depth from the bottom). Maximum currents during ebb were between 4.5 to 5.0 ft/sec at the surface and 3.0 to 3.5 ft/sec at the bottom.

As the literature identifies, only two sources have developed estimates of the tidal prism through East Pass: the 1939 U.S. Engineers Office report and the 1992 USACE study (Morang 1992). The 1939 report estimates  $1.23 \times 10^9$  cu ft of water moves through the inlet on flood and  $1.59 \times 10^9$  cu ft on ebb. These estimates correspond to maximum discharges of 50,000 cfs on flood and 53,000 cfs on ebb. The discrepancy between the two is attributed to artesian wells located in Choctawhatchee Bay and freshwater runoff into the bay. Adjacent tidal inlets may also play a minor role. The 1992 study does not present computed estimates of the total tidal prisms. However, it does present graphs of the measured discharge through the pass. Numerical integration of the discharge curves for 16 May 1984 and 16 April 1987 gives flood tidal prisms of  $2.49 \times 10^9$  cu ft and  $1.25 \times 10^9$  cu ft, respectively (with maxima of 88,000 cfs and 63,000 cfs), and ebb prisms of  $4.16 \times 10^9$  cu ft and  $3.40 \times 10^9$  cu ft (with maxima of 99,000 cfs and 76,000 cfs).

Again, the only studies of East Pass current patterns identified in the literature review are reported in the 1939 U.S. Engineer Office report and the 1992 USACE study (Morang 1992). These two field investigations bracket the construction of the jetties. The 1939 study documents the results from drogue studies performed during different times in the tidal cycle. Illustrations of drogue paths show that before jetty construction, the current intensified on the east side of the inlet throat during both flood and ebb tides. The report states that despite their release location, all the drogues that passed through the inlet moved toward the east side of the inlet where they experienced high velocities.

The 1992 USACE report (Morang 1992) details experiments performed in the years 1983, 1984, and 1987. Plots of the currents in East Pass Channel again show an intensification of current velocity on the east side of the pass. Morang (1992) suggests the ebb current impinging on the east bank is the main cause of the rapid erosion of Norriego Point. In addition, Morang (1992) observes that the 300- to 120-deg orientation of the flood and ebb current directions in the northern end of the inlet is almost identical to the 295- to 115-deg orientation of the entrance to Old Pass Lagoon.

This section outlined the tidal hydraulics of East Pass Inlet. Unfortunately, except for the Wave Information Study (WIS) hindcast data, little is known about the wave climate inside the inlet or in the Gulf. In the application of the DMS, the information from this section will aid in the identification of the shoaling mechanisms, as well as provide input into the model applied in the DMS-Analytical Toolbox.

### **East Pass – dredging history**

Reduction of dredging amounts and frequency is the objective of this research. Thus, knowledge of the channel's dredging history is paramount to understanding the behavior of shoaling. As with other pertinent channel information, the channel's dredging history becomes key input data for the DMS-Data Manager. This section documents the dredging activity at East Pass and identifies the areas of shoaling that serve as the test case for the DMS.

Between 1931 and 1995, dredging removed approximately 4 million cubic yards of sediment — about 64,000 cu yd/year — from the project channel. Figure 2 illustrates the locations of the dredge sites and disposal placement areas that encompass all dredging activity at East Pass. Figures 3 and 4 categorize the dredged and placed volumes by site. Some of the designations required considerable estimation. As is usually the case, the dredging records (especially early records) were incomplete. Figures 3 and 4 show that dredging frequency has decreased, while the magnitude of volume dredged has increased. This trend is explained by advances in economic dredging practice. Notably, before 1964, Open Water/Surf Zone designation characterized much of the dredge-material placement. Figure 2 does not denote this area because no reliable record exists of the actual placements. Also, during its early history, side-cast dredges were used to maintain the channel. Thus, the placement area depended on the maintenance location. Table 1 summarizes the dredging activity at East Pass throughout its history.

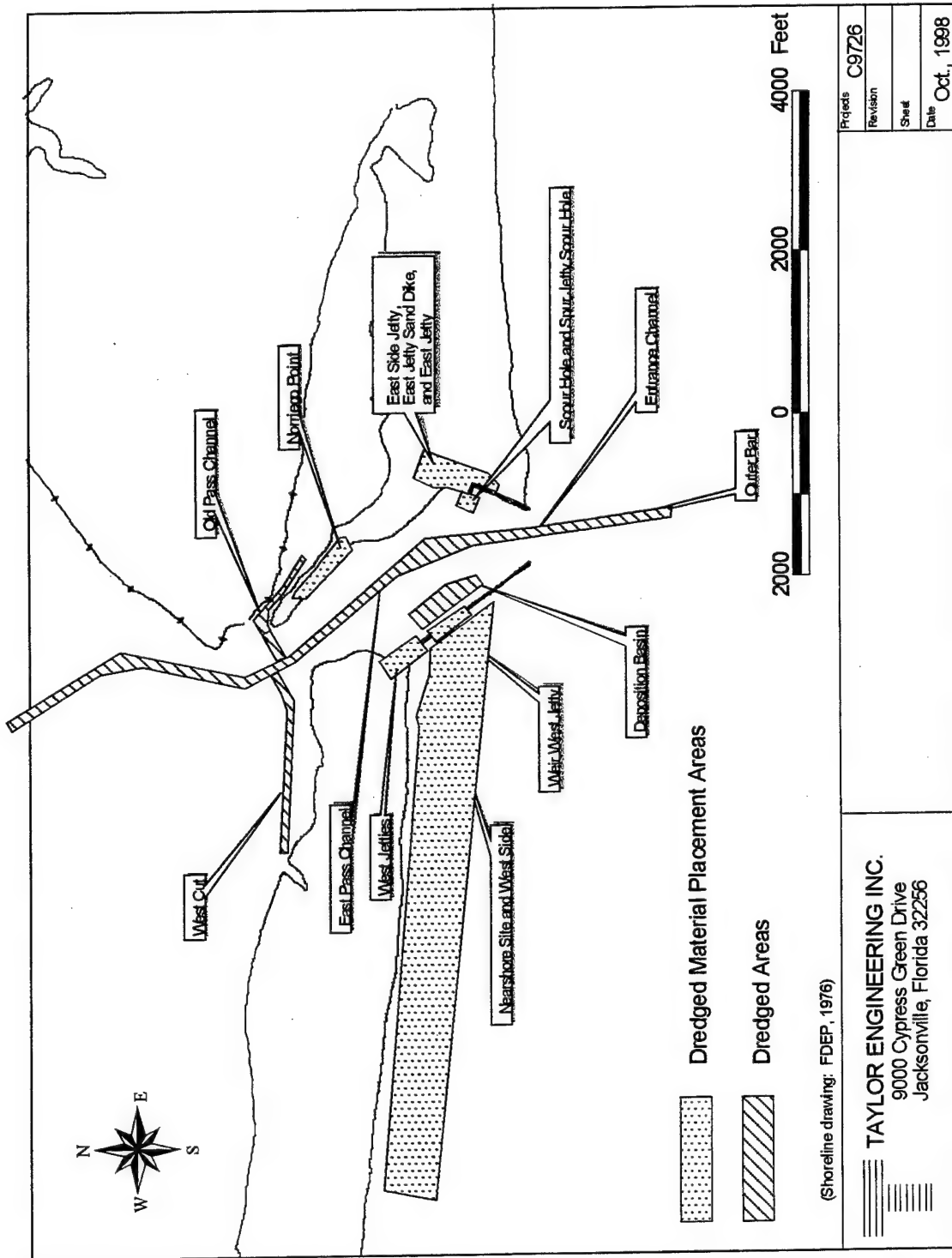


Figure 2. Dredging locations and placement sites

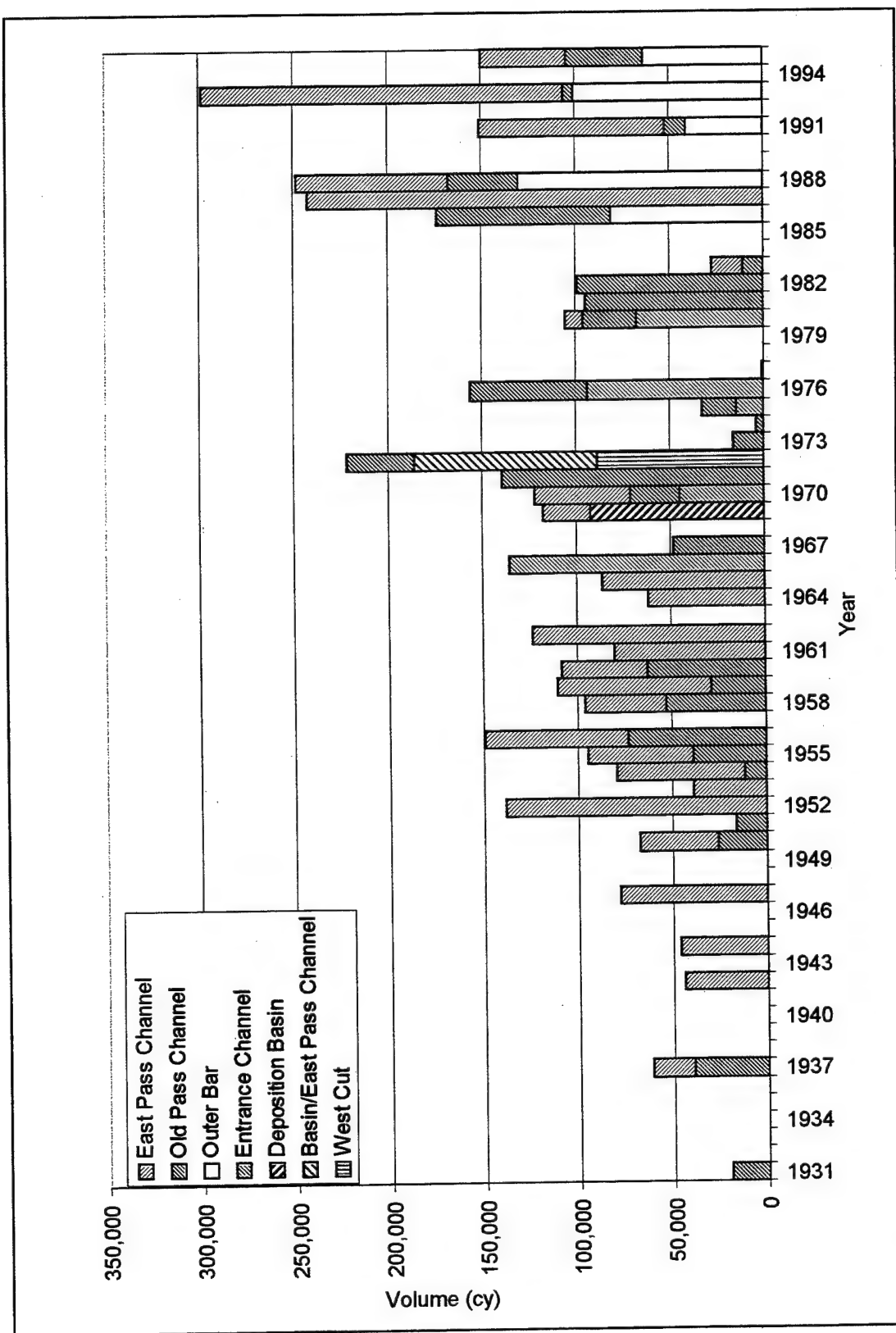


Figure 3. Dredged volumes by site

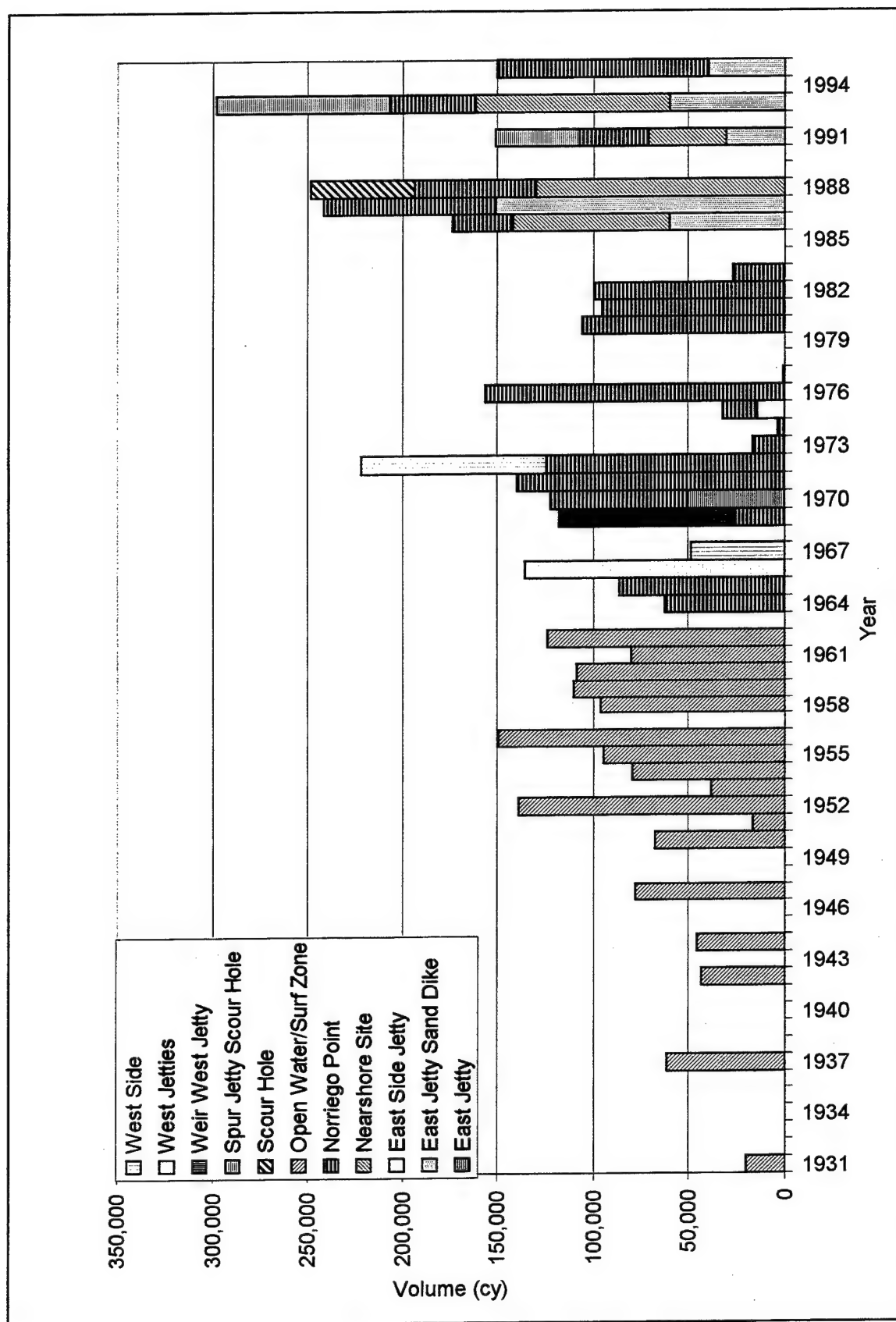


Figure 4. Dredge-material placement by site

<b>Table 1 Summary of Dredging Activity at East Pass (1931–1995)</b>			
<b>Location</b>	<b>Volume, cu yd</b>	<b>First Year Reported</b>	<b>Last Year Reported</b>
<b>Dredging Site</b>			
East Pass Channel/ Deposition Basin	2,083,779	1937	1995
Entrance Channel	356,939	1966	1980
Old Pass Channel	1,142,459	1931	1995
Outer Bar	417,206	1986	1995
West Cut	89,029	1972	1972
<b>Dredge-Material Placement Site</b>			
East Jetty	407,526	1970	1995
Nearshore Site	353,747	1986	1993
Norriego Point	1,408,809	1964	1995
Open Water/Surf Zone	1,355,213	1931	1962
Scour Hole	190,084	1988	1993
West Side	374,033	1966	1972

Table 2 summarizes channel-dredging operations since jetty construction. Notably, most of the material dredged came from the main channel and Old Pass Channel. The overwhelming majority of material-placement activity occurred on Norriego Point. As a comparison, Norriego Point received more than three times as much material as the material bypassed (Nearshore Site).

Examining the dredge plans from recent years in more detail identifies the location of several shoaling “hot-spots,” areas where dredging activity has been concentrated as evidenced by recurrence in the dredging plans. Figure 5 illustrates these locations (crosshatched areas). The three areas have been given names to facilitate discussion. These shoaling hot spots will be analyzed using the DMS in order to test the validity of the methodology.

## Problem Statement

The USACE maintains thousands of miles of navigation channels throughout the coastal waters of the United States and its territories. These Federally maintained channels comprise the maritime heart of the Nation’s waterborne commerce and national defense. As such, their maintenance commands a major share of the USACE O&M budget every year. With the continued ebb and flood of the tide, sediments enter and deposit in these channels, often in areas neither welcomed nor anticipated. Excessive deposition causes shoaling that reduces channel depths, leading to navigational hazards that require frequent and expensive dredging.

Traditionally, once designed and constructed, channels and their ancillary structures have rarely benefited from evaluation against expected performance standards or efforts to reduce their maintenance cost by improving their performance. Consequently, frequent dredging of channel shoals is routinely prosecuted as part of the USACE annual O&M budget at ever increasing cost.

Experience indicates a majority of the most frequently maintained channel reaches and structures share key characteristics that define localized hydraulic conditions and attendant sediment deposition. This tendency for commonality suggests that a reasoned diagnostic

methodology applied to channel hydraulics and associated sediment transport may produce significant benefits, leading to reduced maintenance costs and enhanced project performance. To be effective, this methodology must be easily applied, capable of quickly identifying problems, able to classify problems by key characteristics, and able to facilitate the identification of realistic engineering solutions common to each problem category.

<b>Table 2 Summary of Dredging Activity at East Pass (1969–1995)</b>		
<b>Location</b>	<b>Total Volume, cu yd</b>	<b>Rate of Activity, cu yd/year</b>
<b>Dredging Activity Summary</b>		
Basin/East Pass Channel	96,727	3,720
Deposition Basin	92,791	3,569
East Pass Channel	760,050	29,233
Entrance Channel	220,926	8,497
Old Pass Channel	724,339	27,859
Outer Bar	417,206	16,046
West Cut	89,029	3,424
<b>Disposal Site</b>		
East Jetty	50,486	1,942
East Jetty Sand Dike	342,395	13,169
East Side Jetty	14,645	563
Nearshore Site	353,747	13,606
Norriego Point	1,260,193	48,469
Scour Hole	54,595	2,100
Spur Jetty Scour Hole	135,489	5,211
Weir West Jetty	92,791	3,569
<b>Total Material Dredged</b>	<b>2,304,341</b>	<b>88,629</b>

The DMS attempts to embody this methodology by taking a three-pronged approach to the evaluation of shoaling problems. The DMS-Data Manager component consolidates all the pertinent information concerning maintained channels in one place and in an easily interpreted graphic format. The DMS-Manual, an encyclopedia for shoaling signatures, simplifies the classification of shoaling mechanisms through comparisons with generalized illustrations, example photos, and case studies. The DMS-Analytical Toolbox contains a suite of programs and analytical models for advanced analysis of shoaling problems. In addition, this component provides recommendations for output format to facilitate diagnosis of shoaling mechanisms and investigation of solutions.

This report seeks to evaluate the DMS concepts through the application of each of the DMS modules on a demonstration site, the shoaling hot spots at East Pass Inlet (Figure 5).

## Objectives and Procedures of this Study

The objective of this study is to determine the causes of the shoaling in the maintained channels at East Pass Inlet and to recommend a solution that will reduce the frequency and cost

of dredging, and improve navigation safety. The objective is met through the application of DMS concepts and methodology.

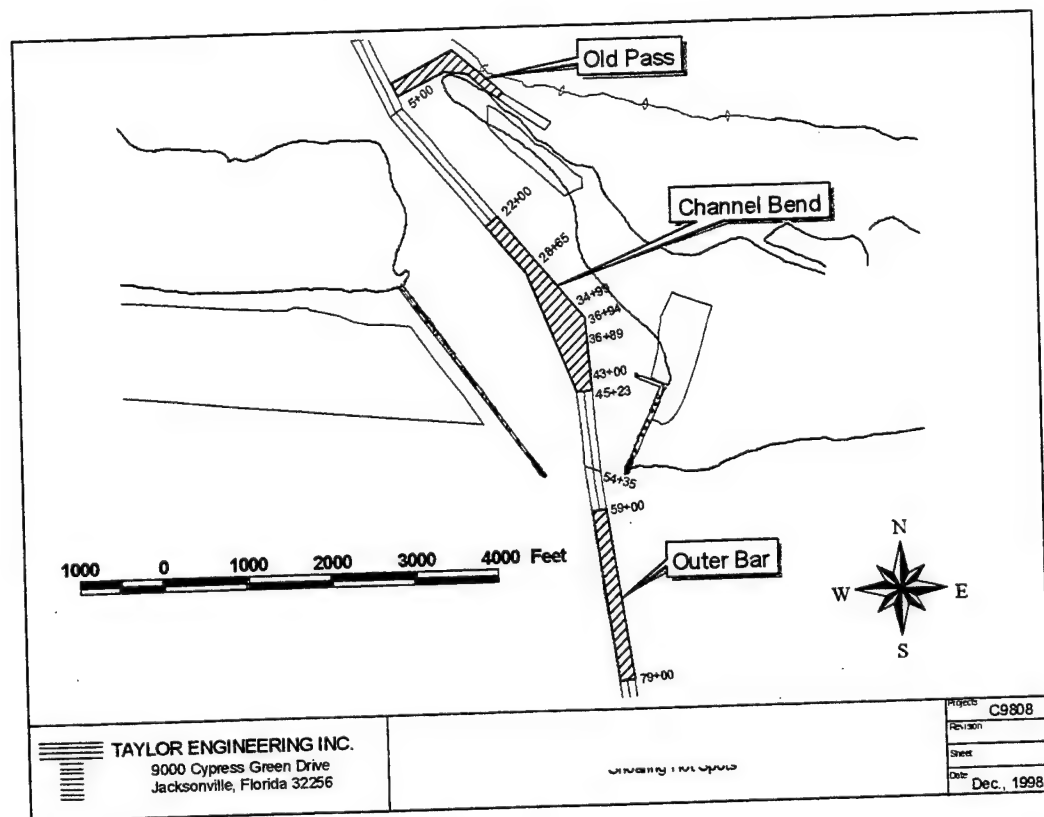


Figure 5. Shoaling hot spots at East Pass

This second DMS application employed the following procedure:

- Make site visits, review the existing literature, discuss the physical processes with those possessing local knowledge, and enter all available information into the DMS-Data Manager.
- Based on the information displayed in the DMS-Data Manager, classify the types of shoals by reference to the DMS-Manual.
- Applying tools in the DMS-Analytical Toolbox, perform an analysis of the shoaling patterns that includes a hydrodynamic model, a wave refraction model, and simple sediment-transport calculations.
- Synthesize information and results from Items *a-c* and make recommendations for reduction of channel shoaling.

This report documents the results of this DMS application. Chapter 1 gives a background of the DMS methodology, a description of the study area including the inlet history and physical processes, and the problem statement and study objectives. Chapter 2 contains a description of the DMS-Data Manager and the example application at East Pass. Chapter 3 reviews the DMS-Manual and employs it to classify the shoaling problems at East Pass. Chapter 4 outlines the DMS-Analytical Toolbox and presents the application of a few of its tools to the shoaling at East Pass. Chapter 5 presents conclusions and recommendations.

## 2 DMS-Data Manager

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### Data Manager Overview

The DMS is intended to assist those responsible for inlet and channel design and maintenance in assessing both the root causes of shoaling and the implications of proposed changes to such systems. One important component of the DMS is the Data Manager, a graphically based tool that allows the user to view all relevant data representing conditions within the area of concern. This software tool brings modern data visualization technology to the user's desktop — as such, it leverages recent advances in Geographic Information Systems (GIS).

The Data Manager is a customized extension of the commercially available GIS software package ArcView from Environmental Systems Research Institute (ESRI), Redlands, California. Taylor Engineering, Inc., of Jacksonville, Florida, in conjunction with the CHL is developing the Data Manager. In combination with the Data Manager User's Guide (presently under development), the software assumes the user has minimal experience with GIS systems, and as such, development has proceeded with the end user in mind. Numerous wizards aid the user during assembly of a comprehensive project database. Data Manager leverages the flexibility of data formats available for use within ArcView to minimize format conversions and simplify the assembly process. Additionally, the Data Manager will incorporate several analysis tools to allow the user to perform volumetric comparisons to address what-if questions. The Data Manager offers features that could become an integral part of the daily routine of those who maintain the country's waterways.

Report generation is the main product of the Data Manager. Users can produce consistently formatted reports from their data via the reporting option available. This option allows examination of past dredging records in a tabular and/or graphical format to aid in analysis and review of shoaling areas. Examples of such reports may include anticipated costs of upcoming projects, daily progress reports of active projects, summary statistics (i.e., total volumes, annual volumes) for user-defined areas, plus several other reports.

### Software requirements

The DMS-Data Manager works on the Windows NT 4.0 operating system and in conjunction with the latest release of ArcView (presently, Version 3.1) — extending the base functionality of the ArcView environment. Support of other

operating systems is not scheduled at this time. The Data Manager extension will incorporate ESRI's 3-D Analyst extension to develop and view bathymetric surfaces and to calculate sediment volumes. The 3-D Analyst, which is not necessary to view much of the base map data, is a central element of the DMS-Data Manager. The CAD Viewer extension, provided with the base ArcView package, allows incorporation of CAD drawings in AutoCad (.dwg), AutoCad export (.dxf), and MicroStation (.dgn) formats within the database. Additionally, the latest version of the software supports many common image formats, allowing easy viewing of existing and historic site conditions. Finally, the Data Manager accesses the Crystal Reports for ArcView application to generate many of the available professional reports.

## **Data requirements**

The Data Manager supports a wide variety of data formats. These include Arc/Info coverages, shapefiles (ArcView's native format), AutoCad drawings (through release 14), MicroStation files, Dbase databases, various text-based data files, and digital images. The initial step required during development of the database is selection of a common coordinate system (typically State Plane or UTM) and units (feet, meters, decimal degrees) to be applied to all the data. This flexibility provides a common reference for the Data Manager and allows accurate data layering. The required data falls into five classifications: base map information, bathymetric surveys, dredging records, digitized photographs, and miscellaneous. Each classification is discussed in detail below.

### **Base map**

Base map information can be anything the user associates readily with the project area. Examples include project (channel) boundaries, stationing information, aids to navigation, shoreline positions, shore-protection structures, marina and port facilities, sensitive environmental areas, deposition areas, hazardous areas, shipwrecks, fish havens, reefs, utilities, buildings, roads, and bridges. Typical formats for base map data will include Arc/Info coverages, shapefiles, or the two CAD formats. The World Wide Web and in-house GIS personnel provide numerous sources for base map data from various Federal, State, and local Government agencies.

### **Bathymetric surveys**

The Data Manager accesses standard bathymetric survey data to develop surfaces and grids representing the bathymetry in and around the project area. These data will typically be available in ASCII text files (X, Y, Z) or as contour lines in a CAD drawing. A bathymetry wizard leads the user step by step through the surface-generation process.

### **Dredging records**

Historical dredging records are documented in native ArcView database format and accessed with standard queries through a wizard interface.

Conversion wizards and data input forms are available to translate data to a standardized format. Typical records include date, contractor, location (i.e., station or river mile), horizontal dimensions, depth of cut, design and pay volumes, disposal location, sediment data, and dredge specifications. Typically, preparation of this portion of the database will require manual input of printed data.

One of the advantages to a GIS-based approach is derived from the geographic relationships inherent in the data. For example, dredging records document project performance at a location and thus have a geographic component. Therefore, the data can be referenced to coordinates indicating that location (i.e., stationing, northing/easting, latitude/longitude). These data can then be selected for analysis based initially on the location. Specific problem areas can be isolated and examined to determine trends not readily discernible through standard tabulated data. Several charts (e.g., dredge production and historic shoaling) can be generated based on these records.

### **Digital photographs**

Digital photography provides a means to document general and specific changes to a system over time. These photographs can include aerial photographs, oblique ground-level shots of specific locations, documentary evidence of projects – essentially any aspect of the project that will benefit from photographic evidence. A scanner can convert conventional photographs to digital format for incorporation in the database. Digital images should be converted to JPEG format at a standard resolution of 640 by 480 pixels through third-party software packages. The database includes options to document the source, date, and description of the photograph. The user may easily scroll through the images, select and print those of special interest, and incorporate these images in various reports. Georeferenced aerial photography (i.e., stretched to match the adopted coordinate system) can be incorporated as an additional theme in the project base map.

### **Miscellaneous**

Any additional relevant data fall under the miscellaneous classification. This category can include sediment grain-size curves, tabulated sediment data, a tidal record time series, datum corrections, and sea-level rise rates based upon survey epoch. In a manner similar to that used to maintain the dredge records, the end user incorporates these data into an ArcView database where they become readily viewable and searchable.

## **Case Study – East Pass, Florida**

The case study of East Pass involved testing and evaluating the concepts driving Data Manager development. As stated above, the initial step in developing a DMS-Data Manager project is selection of a common coordinate system for the data. All data shown on the following pages are referenced to the State Plane Coordinate System, North American Datum of 1927, Florida North Zone. Figure 6 shows a typical Data Manager screen. The themes shown along

the left side of the screen comprise the Table of Contents of the viewable data shown in the frame to the right.

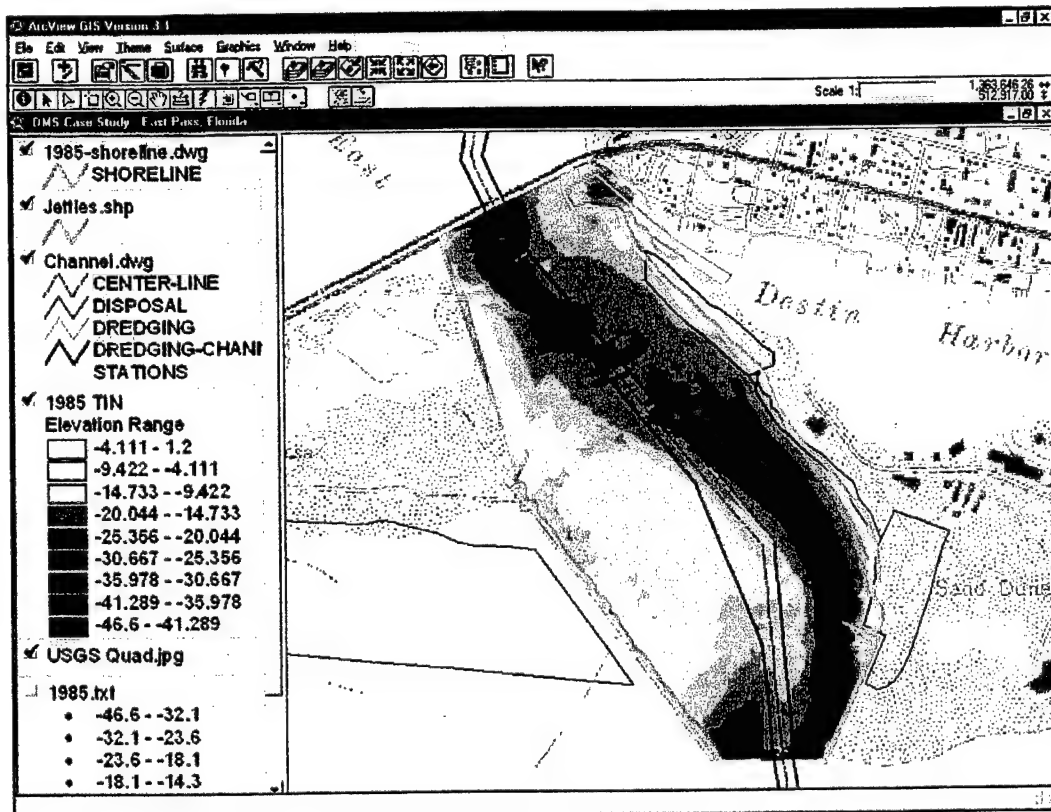


Figure 6. Example of data formats available in the DMS-Data Manager

This example illustrates some of the usable data formats in the Data Manager. First, a georeferenced image of a U.S. Geological Survey (USGS) 7.5-min quadrangle (labeled *USGS Quad.jpg*) provides the underlying base map. An AutoCad drawing (*Channel.dwg*) of the authorized channel and disposal sites has been layered on top of the base map. Above the CAD drawing, the east and west jetties are shown as an ArcView shapefile (*Jetties.shp*). Point data from a comma-delimited X,Y,Z ASCII file (1985.txt) were loaded into the project but not displayed. However, the point data were used to create a triangulated irregular network (TIN) to represent the surface defined by a 1985 bathymetric survey. The TIN has been color coded based on the given elevations to illustrate depths within East Pass. As this single screen shot shows, multiple data formats can now be brought together to provide a detailed view of a project.

With the data assembled in one place, the user can first make some simple observations. First, areas of persistent shoaling become easy to identify. Although personnel with extensive experience on a given project are likely familiar with such areas, documentation in a graphical format helps to clarify and quantify the problem. Figure 7 shows data from bathymetric surveys of East Pass in 1985, 1990, and 1997. Each of these surveys covers areas outside the authorized channels. For clarity, the data have been filtered to display only those falling within the authorized channels. The first two surveys involved standard

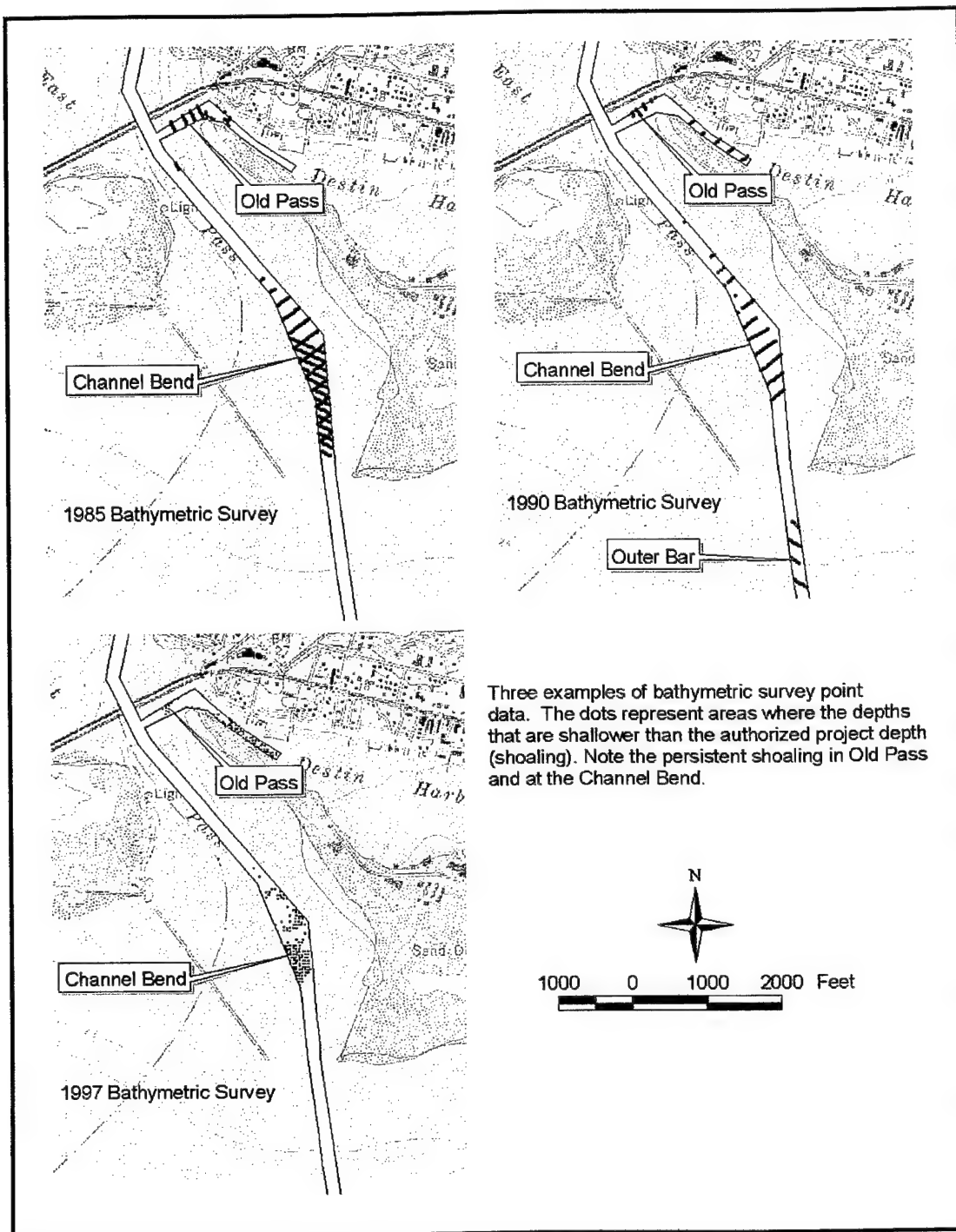


Figure 7. Bathymetric survey comparisons, 1985, 1990, 1997

fathometer surveying techniques. The 1997 survey comes from the SHOALS LIDAR program using airborne laser mapping techniques. Obviously, the data density is significantly increased in the 1997 survey; however, the user can see discernible and repeating patterns in each survey. Notably, the Old Pass entrance channel to Destin Harbor and the Channel Bend within East Pass exhibit consistent shoaling patterns over each survey. The 1990 survey also indicates shoaling within the authorized channel as the channel passes across the ebb-tidal shoal. Once problem areas are identified, they can be compared with the examples given in the DMS-Manual. Further analyses should then follow the techniques included in the DMS-Analytical Toolbox to determine the root cause of the shoaling and to examine potential solutions.

A particular area of concern to the East Pass project engineers is Norriego Point, one of several sites serving for disposal of the dredged material taken from the authorized channels. Norriego Point shelters Destin Harbor from offshore waves that propagate through the jetties into East Pass. Sand historically erodes from Norriego Point into the channels. To document the erosion of Norriego Point, Figure 8 shows four shoreline surveys taken over a 30-month period. The August 1995 shoreline shows conditions before the impact of Hurricane Opal. The January 1996 survey shows conditions following emergency Post-Opal dredging operations that placed sand on Norriego Point. The August 1996 survey shows some of the initial evolution of the shoreline position following placement. Finally, the January 1998 survey shows that the shoreline again approximated 1995 conditions. Chapters 3 and 4 investigate possible contributions that the eroding Norriego Point may have to the shoaling in the authorized channels.

The East Pass case study confirmed the utility of the DMS-Data Manager by providing a quick and simple means to identify problem-shoaling areas. As is found throughout the remaining chapters, the Data Manager is also useful during application of the remaining components of the DMS. Development continues on many of the features identified above. A working beta version of the Data Manager will be available for application to the Year 2 Case Study in Fiscal Year 1999.

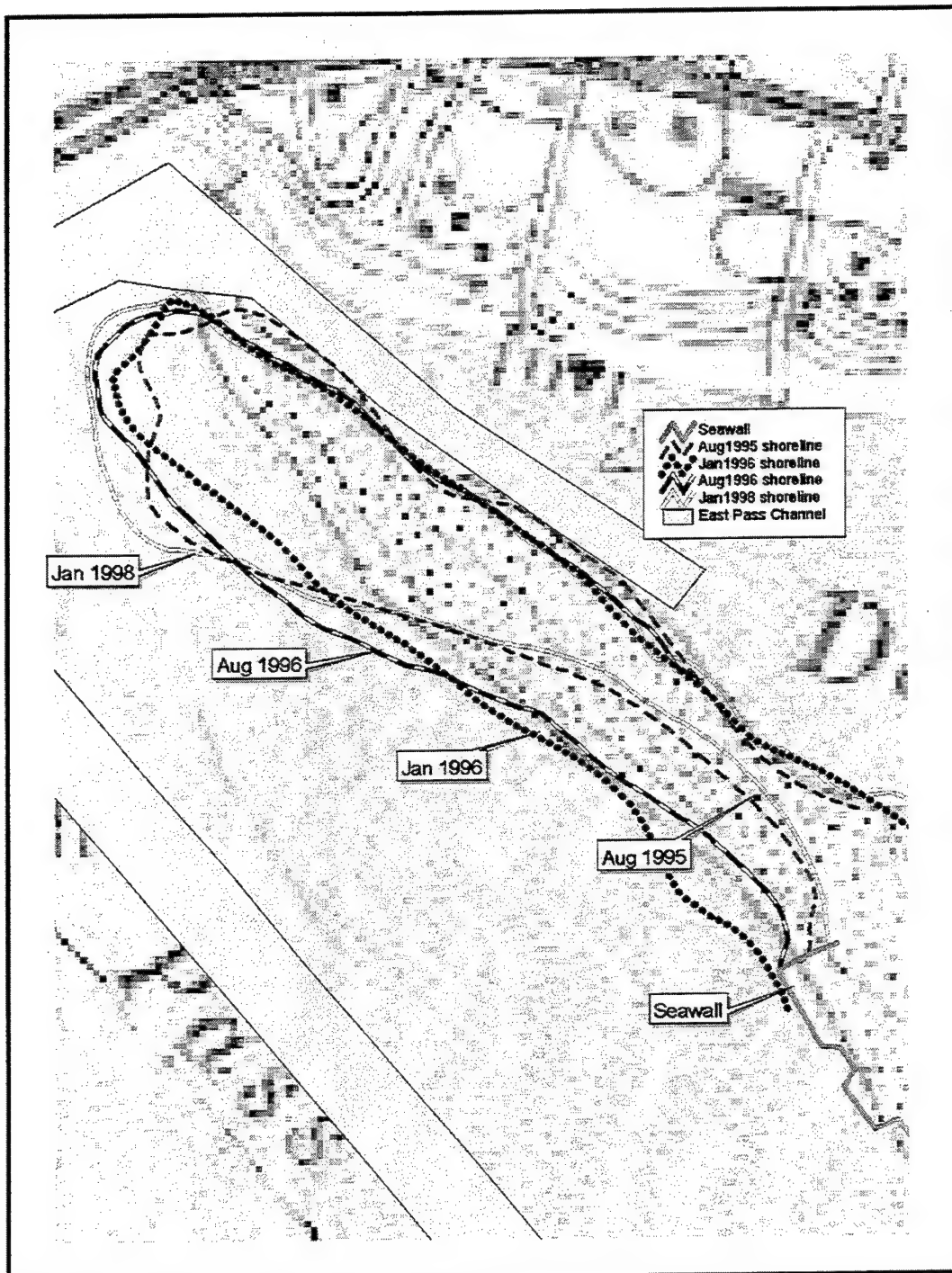


Figure 8. Noriego Point shoreline evolution

## 3 DMS-Manual

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This chapter describes the structure and use of the DMS-Manual. The chapter also presents the manual's application to shoaling problems at East Pass Inlet.

### Manual Description

#### Manual structure

The DMS-Manual is a tool for identifying the type of shoaling problem encountered on a case-by-case basis. As envisioned, the multipage document will serve as a field guide to shoaling problems. Each page of the manual corresponds to a different shoaling pattern. At present, the manual has identified six main shoal classifications or patterns:

- **Horizontal Channel Expansions.** Horizontal expansions of channel boundaries are most times accompanied by an increase in cross-sectional area of the conveyance. Conservation of flow dictates an accompanying decrease in velocity. If the currents are transporting sediment, a decrease in velocity will reduce the sediment-transport capacity and therefore cause sediment to come to rest. This deposition of sediment creates a shoal.
- **Vertical Channel Expansions.** Similar to the previous category, vertical expansions of channel boundaries are also accompanied by an increase in cross-sectional area of the conveyance. Again, conservation of flow dictates an accompanying decrease in velocity. If the currents are transporting sediment, a decrease in velocity will reduce sediment-transporting capacity and, therefore, tend to cause deposition of sediment. This deposition creates a shoal at and after the expansion.
- **Sheltered Areas.** Protuberances (e.g., headlands and structures) in a conveyance cause flow to accelerate at the obstruction by reducing the channel cross-sectional area. This acceleration increases the sediment-transport potential at the obstruction. Downstream of the obstruction, complicated flow patterns create regions of low velocity and low turbulence in addition to flow readjustment to the increased cross-sectional area. Lower velocities reduce the sediment-transport potential. This reduction increases the probability of sediment deposition. This

type of shoaling is usually accompanied by a region of scour or erosion upstream of the shoal.

- **Changes in Channel Alignment.** Changes in channel alignment can refer to either natural changes (meandering) or artificial changes (e.g., structurally redirected flows). A change in channel alignment redirects the flow momentum. Conservation of momentum dictates the establishment of secondary currents within the conveyance that spin about the flow axis. These vortices tend to erode sediment from the outer bank of a bend and deposit it at the inner bank.
- **Multiple Channels.** Intersections of watercourses can create complicated flow patterns. Often, these patterns include areas of flow acceleration and deceleration. Decrease in velocity implies a decrease in sediment-transport potential and hence an increase in the probability of shoaling. Shoaling probability increases where one of the intersecting channels is a riverine sediment source.
- **Enhanced Sediment Forcing.** This miscellaneous category of channel-shoaling classification includes mechanisms that do not fall into the above categories. These shoaling mechanisms include sediment transport by winds, waves, storms, and large-scale current patterns.

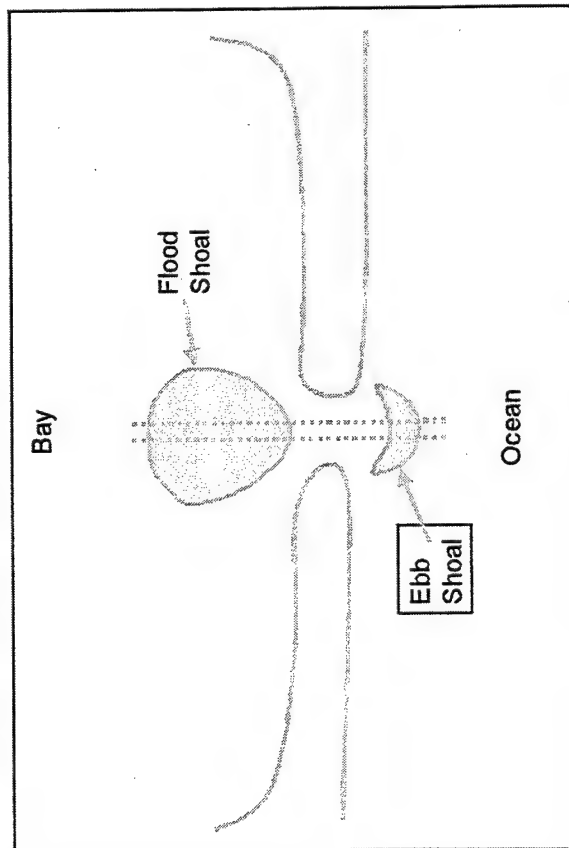
In the future, each of the above categories is expected to be further divided into subcategories. Each page of the manual will be devoted to one of the subclassifications of channel shoaling. As an example, the Horizontal Channel Expansions category may be divided into three subclassifications: (a) Expansion into Ocean – Ebb-Tidal Shoal, (b) Expansion into Bay – Flood-Tidal Shoal, and (c) Areas of Shoreline Recession.

Each page of the manual will feature the same format. Figures 9 through 12 show examples of envisioned manual format. At the top of each page is the main shoaling classification and subclassification. Below this heading on the left of the page is a general diagram of the shoaling patterns and forcing mechanisms. These diagrams are drawn as simply as possible to aid in identification of shoaling patterns that can vary significantly in size and shape. Below the drawing is a short description of the shoal. Below this is a short narrative describing the physical processes that create the shoal. At the bottom left is a reference containing a case study dedicated to an example of this type of shoal. An aerial photograph depicting the shoal pattern is located on the right of the page, below the heading. Below the photograph is a description of the depicted site, the date of the photograph, and a description of the project and shoaling history.

## **Manual use**

The DMS-Manual is a diagnostic tool. The engineer responsible for channel maintenance begins the shoal-classification process by collecting all pertinent data about the channel. These data will include aerial photographs, channel hydrographic surveys, and dredging history. Data collection in the DMS-Data

## Horizontal Channel Expansions



**Description:** A crescent- or box-shaped shoal that forms at the seaward end of a tidal inlet. Shape of this shoal depends on the area's wave climate.

**Processes:** Wave-induced sediment transport (littoral drift) interrupted by the inlet is directed seaward by the ebb tide. Sediment settles out in the region of relative calm away from the strong currents near the inlet mouth. The decrease in velocity results from the depth-dependent horizontal spreading of the ebb jet.

**Case Study:** Not Available

## Expansion Into Ocean – Ebb Tidal Shoal



**Site:** Big Marco/Capri Pass, Collier County, Florida  
Photographed 10/13/69

**Project:** Depth of 8 ft MLW

**Shoaling History:** Unknown

Figure 9. Example page of the DMS-Manual (Horizontal Expansions: Expansion into Ocean – Ebb Tidal Shoal)

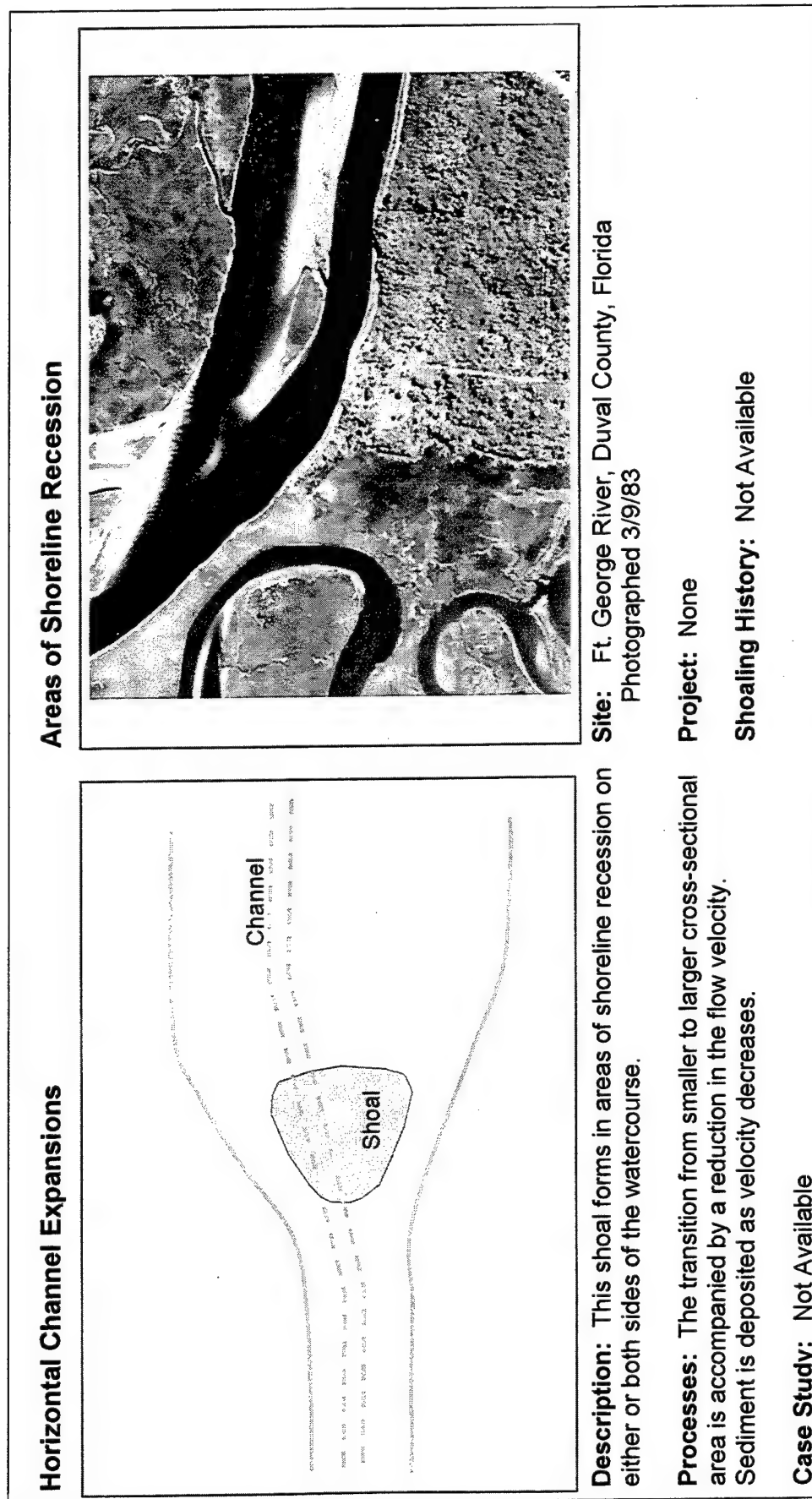


Figure 10. Example page of the DMS-Manual (*Horizontal Expansions: Areas of Shoreline Recession*)

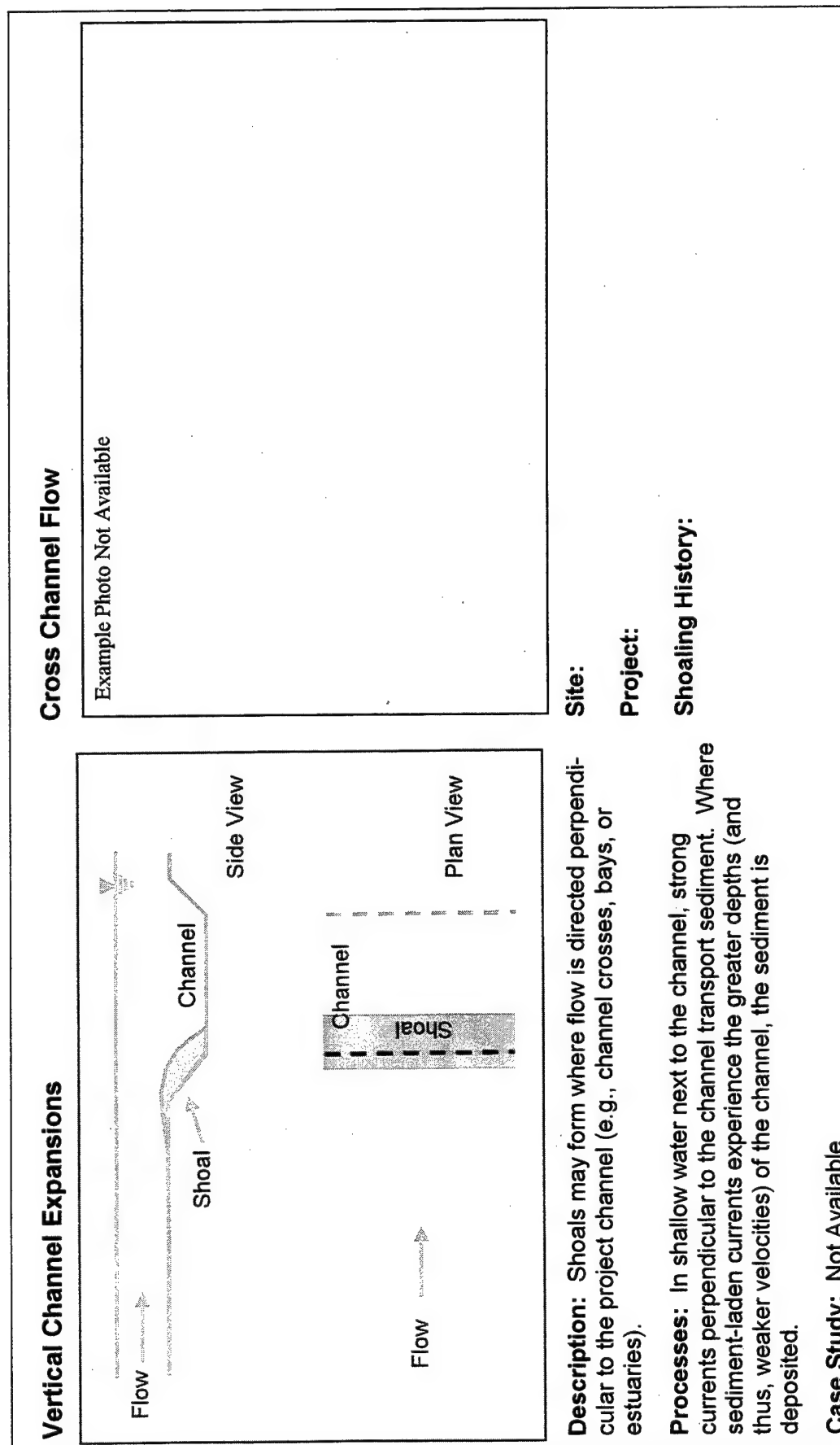


Figure 11. Example page of the DMS-Manual (*Vertical Expansions: Cross Channel Flow*)

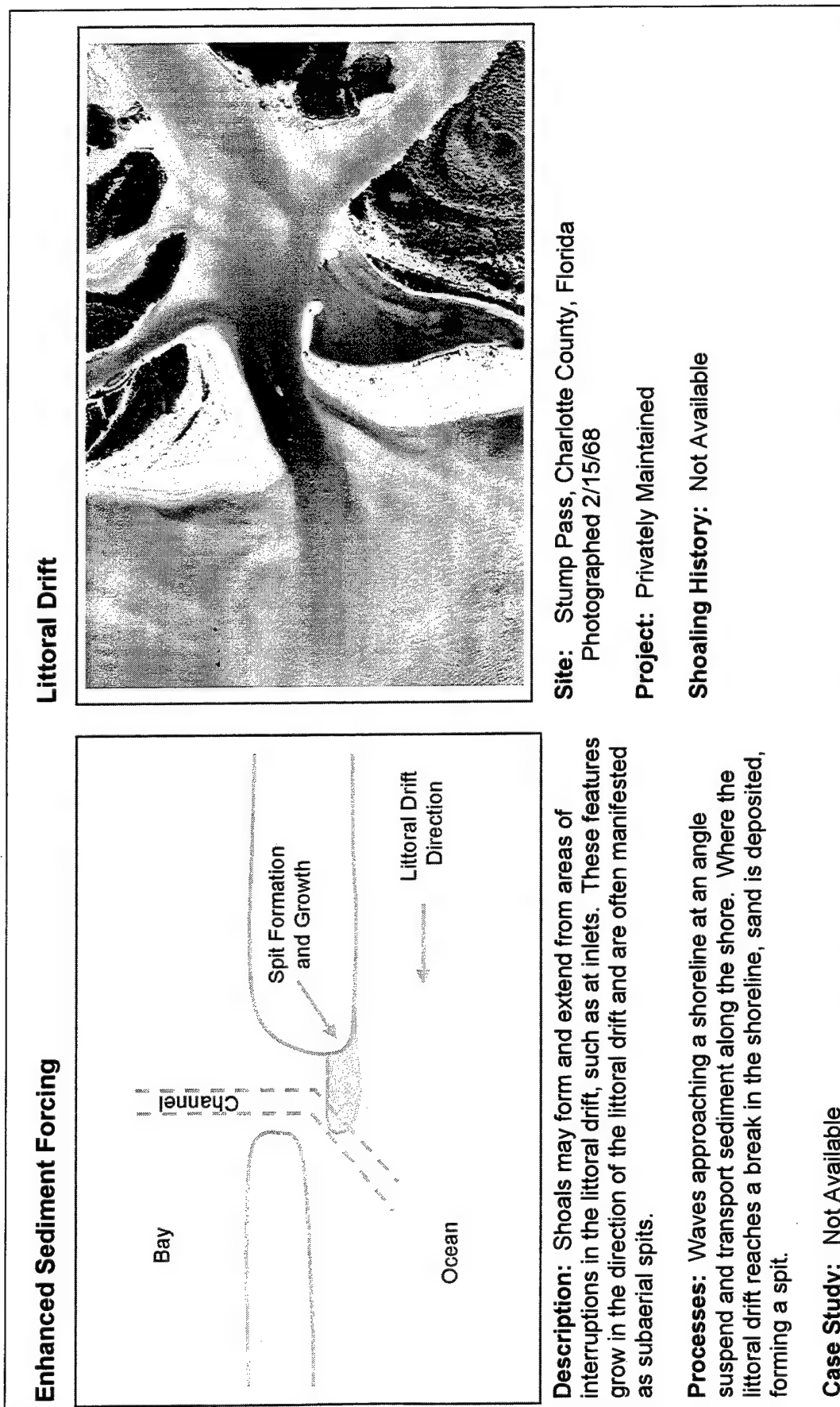


Figure 12. Example page of the DMS-Manual (*Enhanced Sediment Forcing: Littoral Drift*)

Manager allows the engineer to obtain a visual picture of the size and location of the shoal. Upon completion of this task, the engineer then consults the DMS-Manual. Having obtained a visual image of the shoal, the engineer compares this image with the general drawings and example photographs. This process results in the selection of one or more classifications that may describe the shoal. Upon reading the description of the shoal and the physical processes that created it, the engineer should be able to narrow the choice even further. Obtained before application of the DMS, knowledge about the physical processes in the watercourse (e.g., wind and wave climate, storm history, and current strength and patterns) further simplifies this process.

Identification of the type of shoal is the first step in obtaining more appropriate and cost-effective shoaling mitigation methods. By identifying the type of shoal, the engineer has also identified the processes that led to shoal creation. Addressing the processes (the disease) rather than the shoaling (the symptom) greatly increases the probability of finding an effective shoaling mitigation method (the cure) in the DMS approach.

Sometimes, shoals may result from several different mechanisms acting in concert. In such cases, the manual lists the shoal under more than one classification. Here, addressing either one or both of the processes provides a successful mitigation method. For example, shoaling occurs in a channel that crosses perpendicular to tidal currents. However, the sediment in the shoal originates from an upstream shoreline exposed to waves. Waves erode the shoreline, and tidal currents transport the sediment towards the channel where the sediment gets deposited because of vertical expansion. Here, the physical processes at play include tidal currents and waves. By only addressing the waves, the engineer may be able to cut off the sediment source rather than try to treat both waves and currents. Regardless, in situations where more than one shoal classification applies, the manual recommends a more detailed analysis by means of using the DMS-Analytical Toolbox.

## Example Application – East Pass Inlet

As identified in Figure 5, the maintained channels at East Pass Inlet exhibit three areas of chronic shoaling. In this example, the type of shoaling in each of these areas is identified using the DMS-Manual and the information collected and contained in the DMS-Data Manager.

### Area 1: Outer Bar

This shoal is located in the maintained channel south of the jetty tips where the channel crosses the ebb shoal. According to dredging records (Table 2), approximately 16,000 cu yd/year are dredged from this location. Figure 7 illustrates the location of the outer bar shoal in 1990. Based solely on the shoal's location, the most likely classification is *Horizontal Expansions: Expansion Into Ocean – Ebb Tidal Shoal* (Figure 9). The sample manual page describes the shoal as follows: "Crescent- or box-shaped shoal that forms at the seaward end of a tidal inlet. Shape of this shoal depends on the area's wave climate." This description exactly matches the morphology encountered at this area. Comparing the generalized figure with Figure 7 further validates this choice.

With the shoal type identified, the next step in the DMS is to identify the shoaling mechanisms and investigate possible shoaling mitigation methods. In this case, the

physical processes that build the shoal involve the transportation of sediment offshore by the ebb jet. The sediment source is the littoral drift on either side of the inlet. Because the only access to Choctawhatchee Bay from the Gulf of Mexico is through the jetties, location of the channel over the ebb shoal is unavoidable. In dealing with channels over ebb shoals, the most common means of lowering dredging costs is to perform regular surveys of the ebb shoal and situate the channel such that it crosses the shoal at the deepest point. The Mobile District has already incorporated this practice into its regular maintenance of the channels at East Pass Inlet in its dredging optimization procedure.

## Area 2: Channel Bend

Beginning approximately 1,000 ft north of the jetty tips and continuing for 2,000 ft in a north and then north-northwest direction, this shoaling hot spot is centered around the southern bend in the project channel. Dredging records do not specify the exact amount removed from this area. One can safely assume, however, that shoaling in this area contributes greatly to the ~38,000 cu yd/year (East Pass Channel plus Entrance Channel categories denoted in Table 2) dredged from the inlet throat. Consultation of the manual gives two possible categories for shoal classification. The first possible classification is *Horizontal Channel Expansions: Areas of Shoreline Recession* (Figure 10). The configuration of the converging jetties (which diverge as one moves south to north) prompts selection of this category. Under this classification, sediment-laden currents travel from an area of flow constriction (between the jetty tips) to an area of low velocity (north of the jetties where the throat becomes wide). Here, with the transport potential reduced, deposition occurs. The sediment source may be either the sediment eroded from the channel between the tips of the jetties or (more likely) the suspended sediment resulting from the inlet's interruption of littoral drift.

The second possible classification is *Vertical Expansions: Cross Channel Flow* (Figure 11). Under this category, shoals form where flow crosses the channel at an angle to the channel's axis. Currents carrying sediments cross from areas of shallow depths to areas of deeper depths. The change in depth is accompanied by a reduction in velocity and hence a reduction in sediment-transport potential. Sediment, therefore, deposits immediately beyond the change in depth. At this channel location, the channel bends from a north/south to a north-northwest/south-southeast orientation. This change in orientation increases the likelihood that, at some point (either on flood or on ebb), currents will cross the channel in a direction other than in line with the channel axis.

Given that the DMS-Manual has identified two possible shoal classifications, this shoaling hot spot is a good candidate for further investigation using the DMS-Analytical Toolbox.

## Area 3: Old Pass

Figure 5 shows the location of Old Pass channel. The channel attaches to the main channel just south of the Highway 98 Bridge. From there, the channel runs in a east-northeast direction until it reaches the tip of Norriego Point. At the tip of the point, the channel bends south acquiring a southeast orientation as it enters Destin Harbor. From 1969 to 1995, this short channel has accounted for approximately one-third of the dredging activity at the inlet.

Upon first inspection, classification of the shoaling behavior seems obvious. *Vertical Expansions: Cross Channel Flow* (Figure 11) appears to match the geometry of this channel perfectly. Both on ebb and on flood, currents cross the channel at approximately right angles. The sediment creating the shoal could come from either Norriego Point or the interior bay (i.e., the flood shoal or the Destin shoreline).

Familiarity with the history of the channel, however, suggests an alternate classification. Before jetty construction, Norriego Point was fully exposed to waves from the Gulf of Mexico. In fact, the point is actually a spit formed through wave-induced sediment transport. The jetties now shelter the spit from waves along certain directions. However, waves approaching the coast from the south still strike the throat's eastern shoreline. Figure 8 shows how much the spit has changed in size and location between 1995 and 1998. Given this information, the classification *Enhanced Sediment Forcing: Littoral Drift* (Figure 12) may also apply. Identifying the mechanisms responsible for shoaling requires application of a wave-refraction model to characterize the wave climate within the throat and a hydrodynamic model to determine the direction and magnitude of currents. Both models are available in the DMS-Analytical Toolbox.

The above three examples illustrate application of the DMS-Manual in conjunction with the DMS-Data Manager for diagnosing shoaling problems. The example pages from the manual identified the possible shoaling mechanisms for the three shoaling hot spots found in the maintained channels of East Pass. Identifying possible classifications has prompted further investigation into shoaling mechanisms through its descriptions of the physical processes responsible for the shoal's creation. Finally, the classification process for Area 3 has underscored the importance of thorough examination of inlet history before applying the DMS.

## 4 DMS-Analytical Toolbox

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This chapter describes the DMS-Analytical Toolbox, presently under development. Included is a discussion on the contents of the toolbox and its use. The chapter presents the application of this DMS component to navigation channel shoaling at East Pass Inlet.

### Analytical Toolbox Description

This component of the DMS consists of a suite of analytical tools for conducting more detailed analyses of channel shoaling. The toolbox is expected to contain various utilities ranging in complexity from simple calculations for determining fetch-limited wave heights to two-dimensional, finite-element, hydrodynamic flow models. These tools will access the data contained in the DMS-Data Manager as input. As such, the development of the Data Manager contains provisions to output information in the appropriate format compatible with these tools.

#### Toolbox contents

The following lists examples of anticipated contents of the toolbox. The label "calculator" indicates that the utility will access the output from one of the other tools to generate new information. Some of the programs were in the process of interface development at the time this case study was conducted.

- **ADCIRC.** The ADCIRC (Luetich, Westerink, and Scheffner 1992) system of computer programs solves time-dependent, free-surface circulation, and transport processes in two and three dimensions. The finite element model is based on the wave-continuity formulation of the shallow-water equations.
- **SMS.** The Surface Water Modeling System (SMS) interface is a pre- and post-processor for ADCIRC (as well as other finite-element numerical models). SMS is a comprehensive graphical user environment for performing model conceptualizations, mesh generation, statistical interpretation, and visual examination of surface water model simulation results.
- **STWAVE.** This tool is a time-independent, finite-difference spectral wave energy propagation model. The STWAVE model (Resio 1987,

1988; Smith, Resio, and Zundel 1999) also includes steepness-limited and depth-limited breaking criteria and the wave-current interaction.

- **Tidal constituent database.** This database (Westerink, Luetlich, and Scheffner 1993) allows the user to manually generate time series of tidal elevations or to use a program to access the full database to generate the time series of both tide elevations and currents for any location along the U.S. east coast, Gulf of Mexico, Caribbean Sea, or U.S. Pacific coast. This database drives hydrodynamic models such as ADCIRC.
- **Sediment-transport calculator.** This utility will calculate sediment-transport rates as an indicator of areas of erosion and accretion. Typically, in DMS applications, it yields indicators of transport potential rather than actual values.
- **Initiation of sediment-movement calculator.** This tool indicates areas of sediment movement. Inputs from ADCIRC and wave estimates determine the shear stress on the bed. From a Shield's diagram, the program identifies areas of live bed (sediment motion) or clear water (no sediment movement).
- **Fetch-limited, wind-generated wave model.** This tool calculates the wave height and period associated with locally generated wind waves. The sediment-transport calculator accesses this information to determine whether wave-driven sediment transport is a cause of channel shoaling.
- **Ebb jet model.** This tool examines the ebb jet issuing forth from an inlet. Based on the work by Özsoy and Ünlüata (1982), this program calculates the velocity distribution of an ebb tidal jet. It takes into account lateral mixing and entrainment, bottom friction, one-dimensional bathymetric changes, and ambient currents. Intended for shoaling problems in channels through tidal inlets, this tool provides estimates of velocity magnitudes that will drive sediment-transport calculations.

The DMS-Analytical Toolbox is not just a collection of programs. It also contains suggestions for display of information generated by these tools. The format for display of information increases the speed of diagnosis and investigation of alternative solutions.

An ancillary goal of the DMS-Analytical Toolbox is to improve interpretative capabilities through adopting innovative graphical formats. Typically, graphical display of hydrodynamic information has been limited to 2-D plots of flow vectors and time-series plots of elevations or integrated flow across an inlet such as in Figures 13 and 14. Although these plots provide some information about the currents in the area, they do not clearly illustrate how the bathymetry controls the flow pattern. Inclusion of false-color contouring of the bathymetry or the velocity magnitude shown underneath the velocity vectors as in Figures 15 and 16 can greatly enhance the diagnostic utility of these figures.

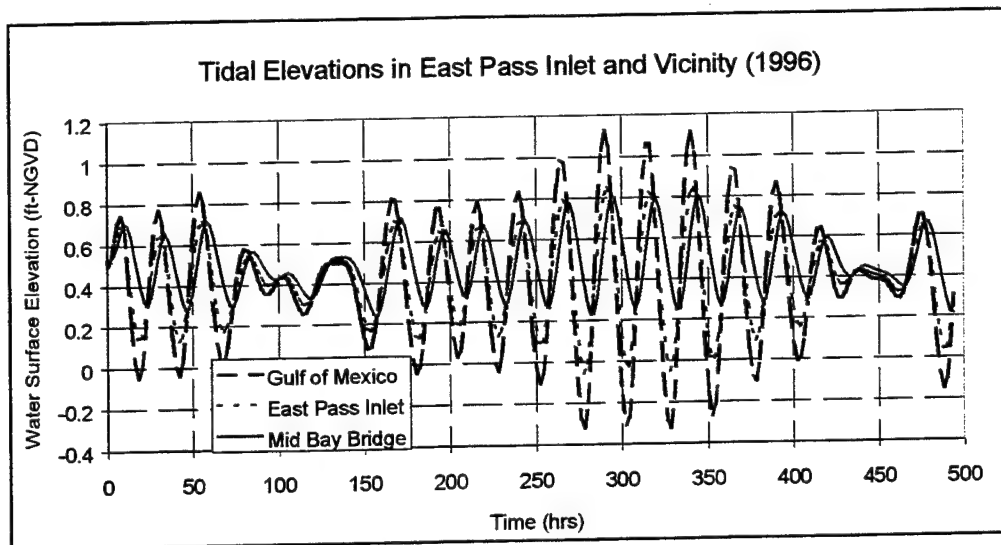


Figure 13. Example of time-series plot

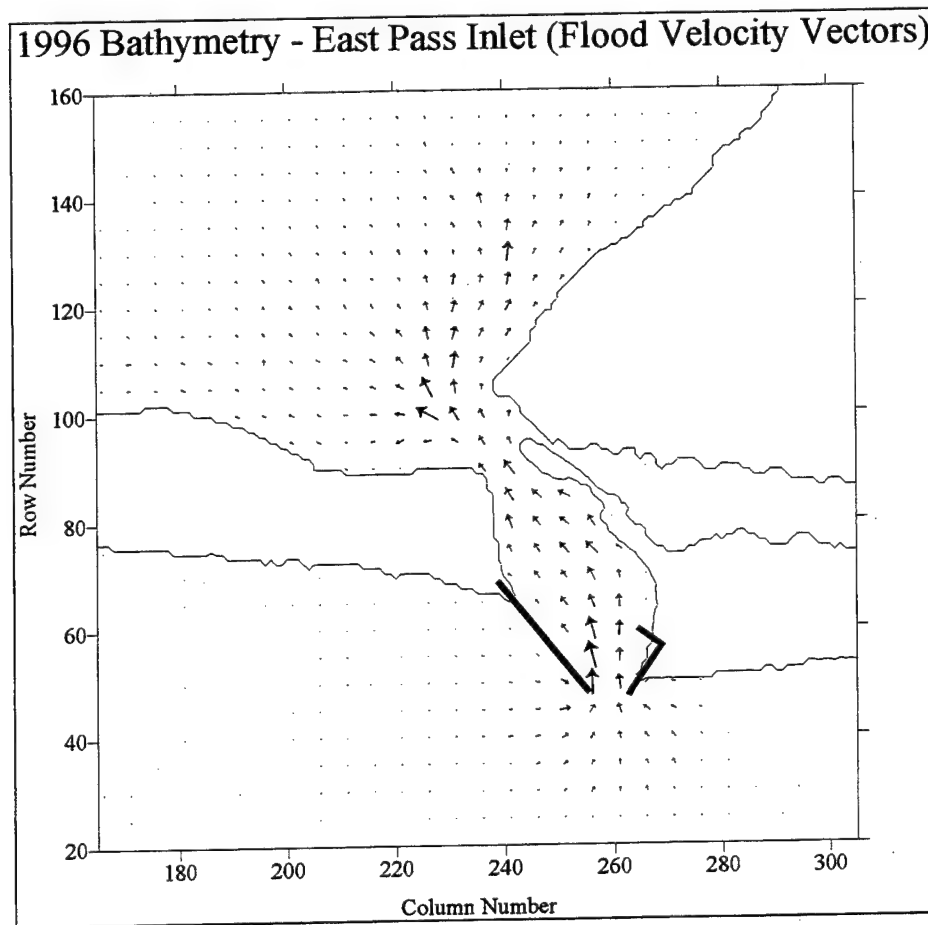


Figure 14. Example of two-dimensional velocity vector plot

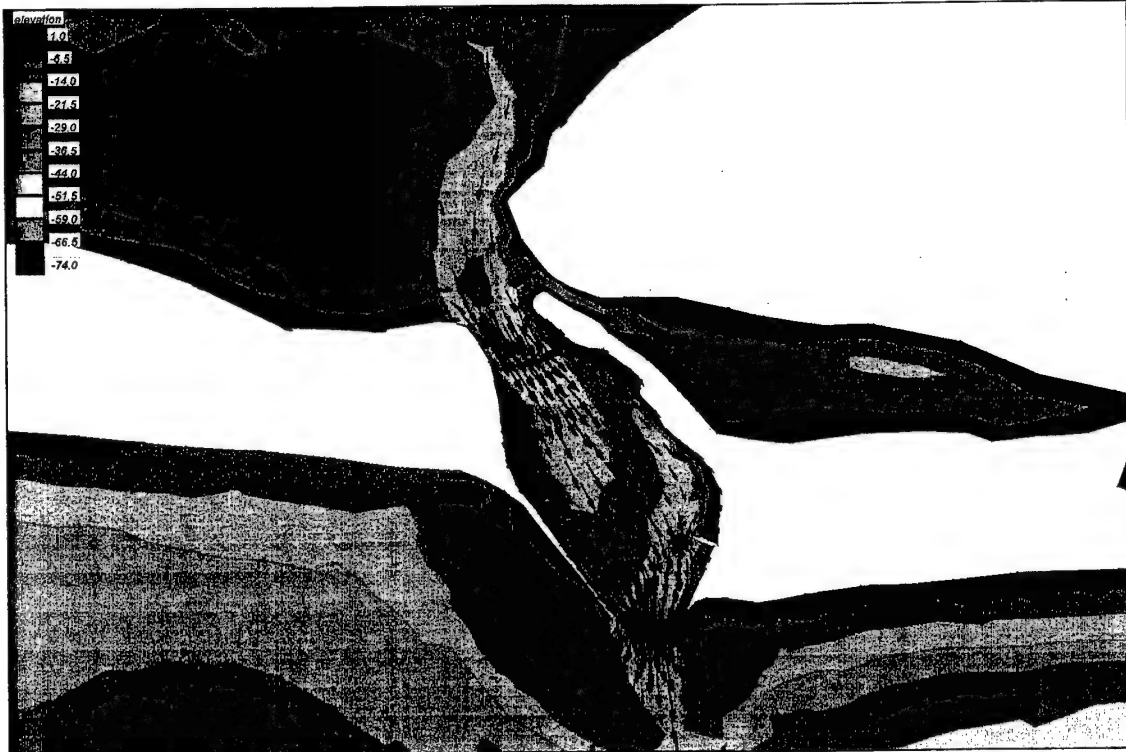


Figure 15. Example of false-color bathymetry with velocity vector overlay

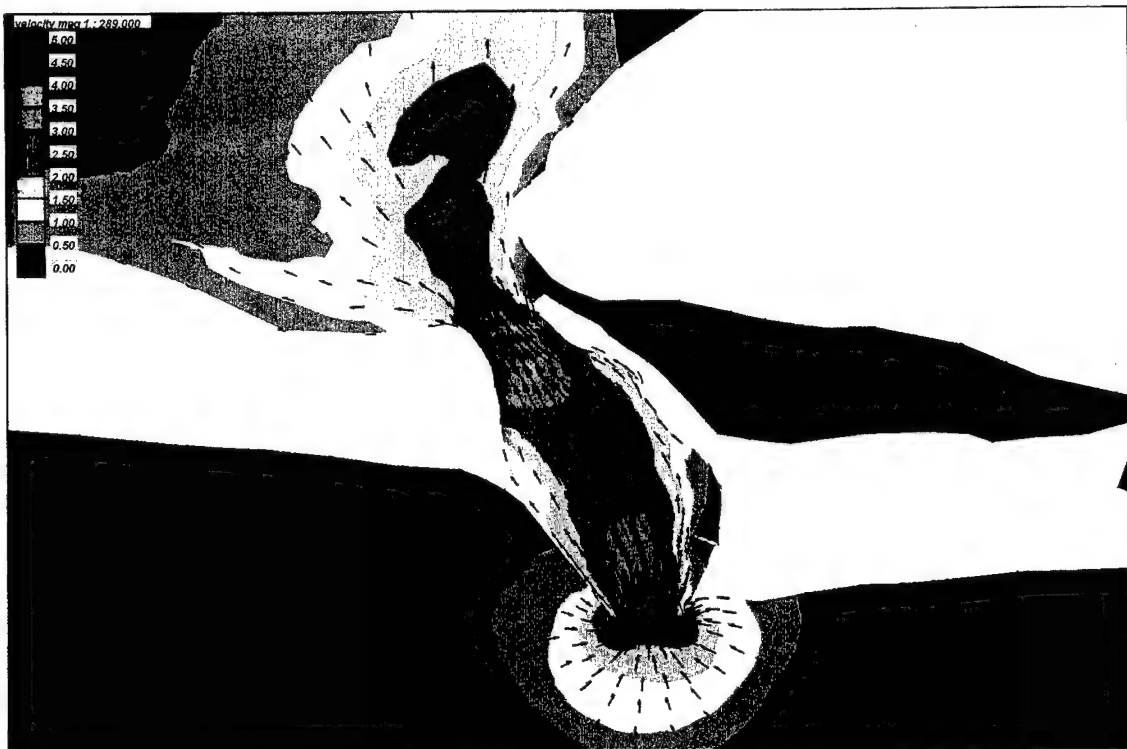


Figure 16. Example of false-color velocity magnitude contour plot with velocity vector overlay

In addition to these types of plots, graphics contours showing differences in two solution sets can provide informative comparisons. For example, Figure 17 was generated to investigate the change induced by jetty construction by plotting the difference in velocity magnitude for hydrodynamic model simulations of a 1947 bathymetry (pre-jetty construction) and a 1996 bathymetry (post-jetty construction). The plot shows the difference in spring ebb-tide velocity magnitude. Positive values (towards the blue end of the spectrum) denote increases in velocity magnitude, and negative values (towards the red end) denote decreases. Units are in feet per second.

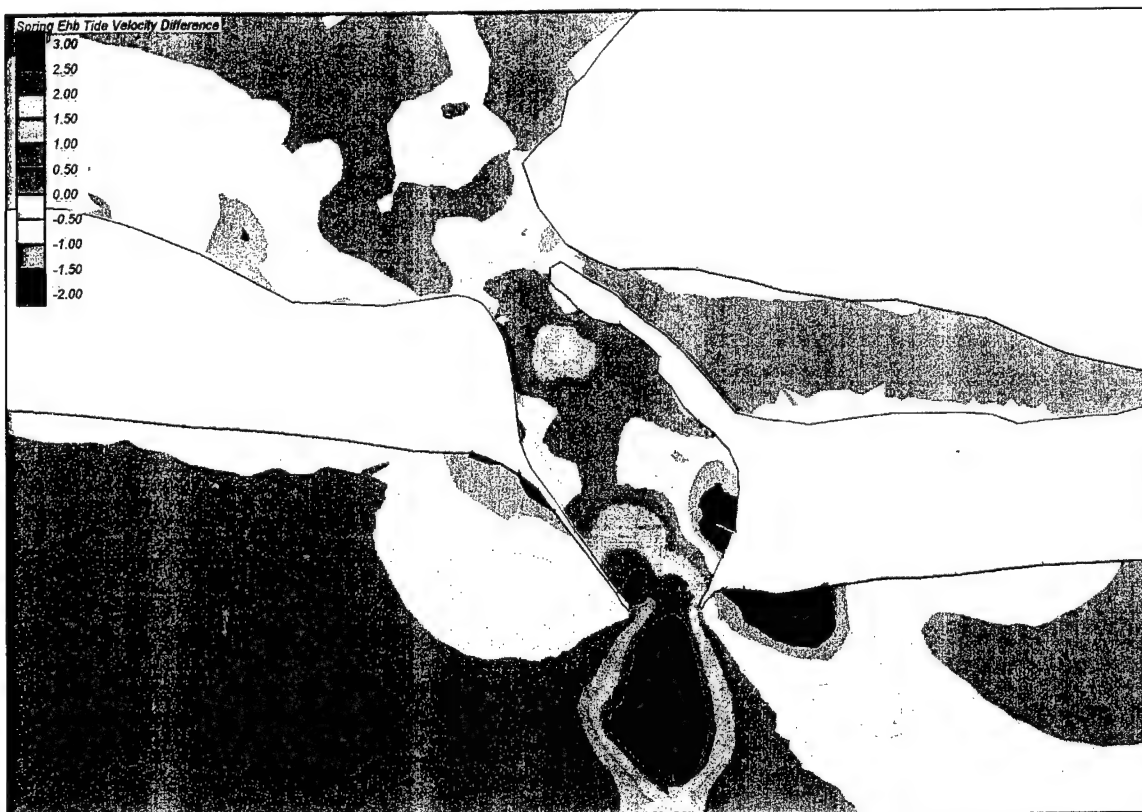


Figure 17. Example of comparison of solutions

The above examples illustrate the diagnostic utility of selecting the correct graphical format for output display from the toolbox models. In addition, the diagnostic benefits gained by adopting the suggested formats increase with the use of standardized formats. Standardizing output formats permit the establishment of an experience database. As more case studies investigate the same tools and display similar information in standard formats, comparisons between case studies of different shoal types will become easier. This standardization will expand the state of the science and utility of the DMS approval.

## Toolbox use

In the application of the DMS to channel shoaling, some conditions often require more detailed analyses of a channel's physical processes either to better identify the shoaling mechanisms or to investigate possible mitigation methods. Obviously, the type and complexity of the investigation will determine the appropriate tool. For example, if the channel being investigated is located in a well-sheltered inland waterway, then setting up a wave-refraction model serves little purpose.

The toolbox is presently in development. With continued application of the DMS, the contents of the toolbox are expected to change as experience and needs direct. Certain types of programs are expected to remain in the toolbox. These include a hydrodynamic model, a wave model, and a sediment-transport calculator. The DMS-Analytical Toolbox will contain recommendations for the output format of these three tools. Development of the recommended formats is ongoing.

Because sediment movement creates shoals, the final form of the DMS-Analytical Toolbox should contain a method for evaluating sediment-transport potential under both quasi-steady currents and waves. As with all sediment-transport investigations, interpreting results requires caution. For example, Yang and Molinas (1982) compared seven sediment-transport (under steady currents) formulae with 1,259 measurements from laboratory and field investigations. The *best* performing formula predicted sediment-transport rates within a factor of two of the measured rates in only 68 percent of the cases.

Application of the sediment-transport calculator produces a spatially variable scalar data set (a contour plot) of magnitude of sediment-transport rate. Interpretation of contours of sediment-transport magnitude is often difficult. One must remember that sediment-transport magnitude does not necessarily correlate to erosion or deposition. Erosion and deposition align more closely to the gradients of sediment-transport rate in the flow direction. If, for example, in a specified control volume, the sediment transport entering the volume exceeds the sediment transport leaving the volume, then most likely, the volume will contain deposition. The appropriate analogy is that of filling a bucket with a hole in the side. If water enters the bucket faster than it comes out the hole, the water level will rise (accretion). If water enters at a slower rate, then the water level will fall (erosion). The most prudent way to interpret these results is to conclude that sediment originates in areas showing sediment transport and moves in the direction of the velocity vectors. Figure 18 illustrates a contour plot of sediment transport overlaid with the water-velocity vectors.

The DMS-Analytical Toolbox can be the most difficult component of the DMS to master. Obviously, implementing a hydrodynamic model or a wave-refraction model requires an investment in learning. The purpose of the toolbox in the analysis of shoaling problems will be to recommend a model choice, to assist in the model setup by identifying the required data in the DMS-Data Manager, and to make suggestions for output formats that best visualize the physical processes that create the shoal. By following this procedure, the DMS makes possible the creation of an experience base from which to compare (and anticipate and avoid) future channel shoaling.

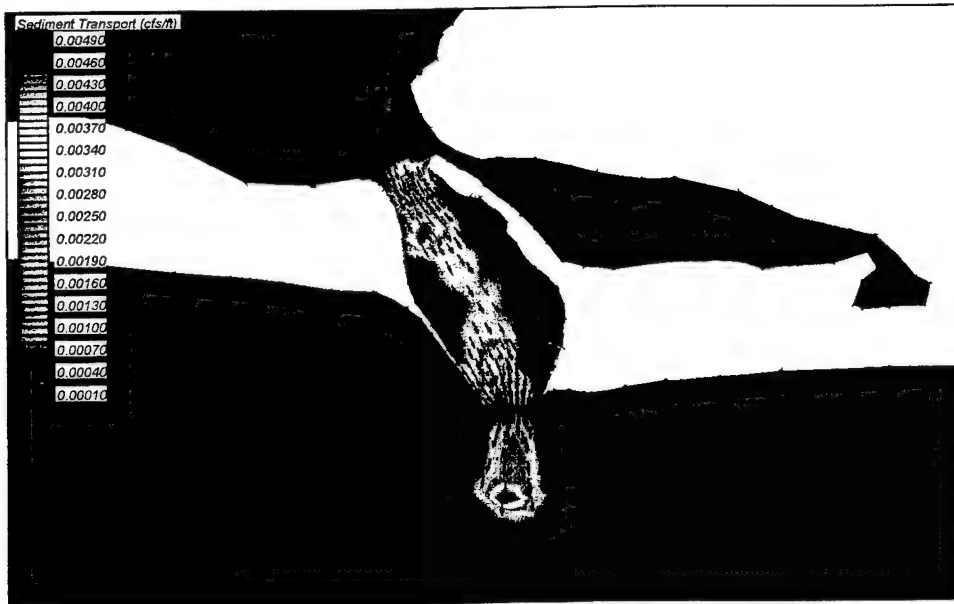


Figure 18. Example of contours of sediment transport

## Example Application – East Pass Inlet

Shoal classification at East Pass Inlet with the DMS-Manual prompted investigation of the physical processes with two types of models that will become available in the DMS-Analytical Toolbox. First, a hydrodynamic model determines the magnitude and direction of the inlet's currents. Second, a wave-refraction model characterizes the wave climate in the inlet throat.

### Inlet hydrodynamics

As identified in Chapter 1, the maintained channels at East Pass Inlet contain three channel shoaling hot spots (Figure 5). For two of the areas (Channel Bend and Old Pass), the application of the DMS-Manual in Chapter 3 gave more than one classification of shoal type. For both these areas, the physical processes involved currents through the pass. This prompted the need to investigate the inlet hydrodynamics. This section details the application of RMA2 (Thomas and McAnally 1985) to resolve the current patterns at the shoaling areas. RMA2, a 2-D, depth-averaged, finite-element, hydrodynamic numerical model, computes water-surface elevation and horizontal velocities for subcritical, free-surface flows. The program computes a finite-element solution to the Reynold's form of the Navier-Stokes equations.

Figure 19 depicts the bathymetry input to RMA2. The constructed bathymetry reflects a combination of the following hydrographic surveys, which characterize the area given in parentheses:

- 1997 USACE SHOALS Lidar Survey (Inlet Vicinity)
- 1996 USACE SHOALS Lidar Survey (Inlet Vicinity)
- 1987 NOAA Nautical Chart #11385 (Choctawhatchee Bay)
- 1995 NOAA Nautical Chart #11388 (Gulf of Mexico)

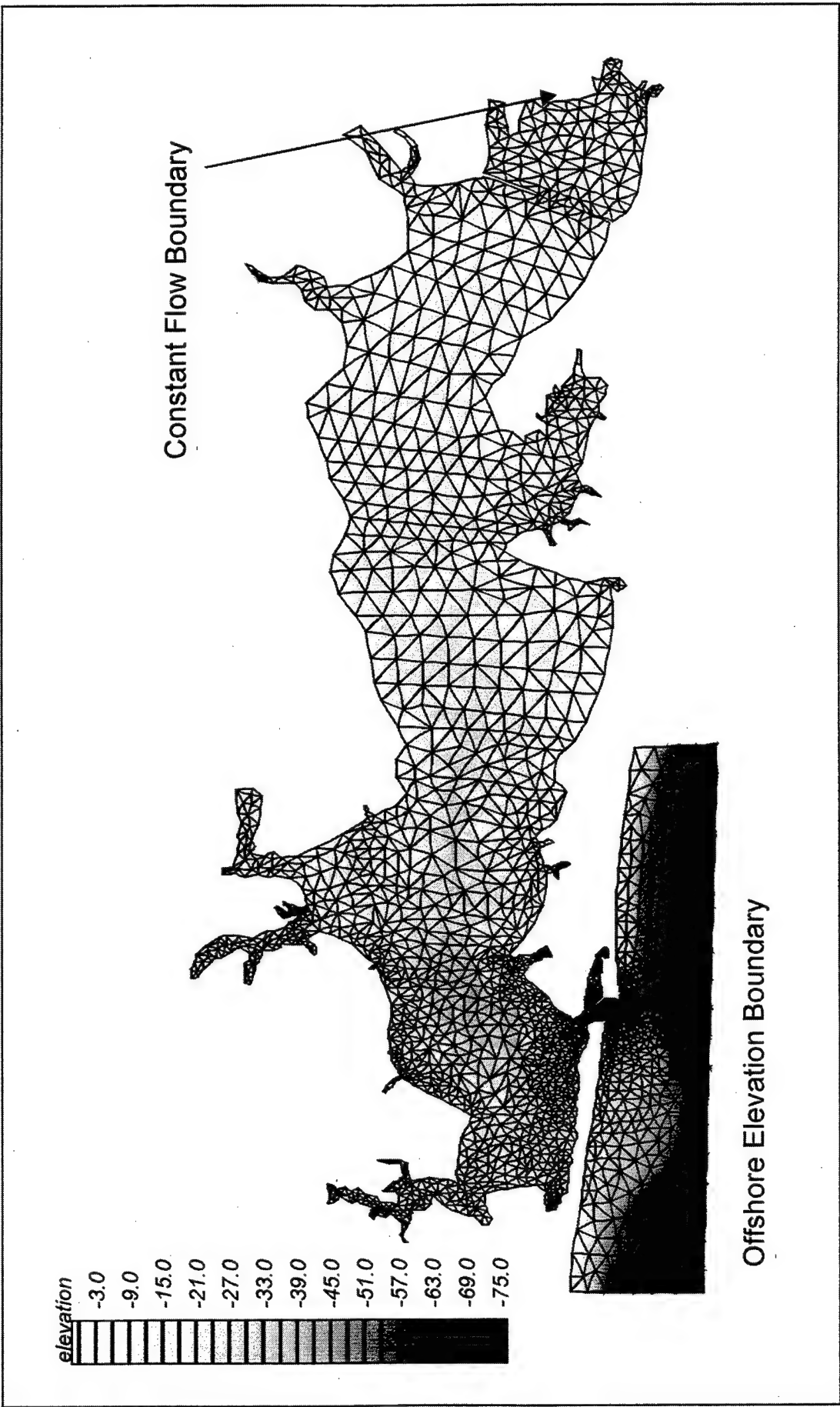


Figure 19. RMA2 solution mesh for East Pass Inlet and vicinity

Two boundary conditions were specified for the model. Month-long tide gauge records provided the water-surface elevations at the offshore boundary located approximately 2 miles offshore. Averaged flow measurements of the freshwater influx specified the flow boundary condition situated across the Choctawhatchee River Delta on the eastern border of the bay.

Figures 20 and 21 depict channel currents during spring flood and spring ebb. Velocity vectors are overlaid on contour plots of the velocity magnitude. The solid black lines in the figures indicate the location of the maintained channels. Magnifying the areas of interest, Figures 22 through 25 depict the currents over the shoaling hot spots.

In Chapter 3, the DMS-Manual identified two possible shoal classifications for the shoaling hot spot at the channel bend. These were shoaling caused by horizontal expansion of the channel (through shoreline recession) and shoaling caused by vertical expansion of the water column (i.e., shoaling from currents crossing the channel at an angle to the channel's axis). Figures 22 and 23 illustrate current patterns in the vicinity of this shoal. Examination of the gradient of the velocity-magnitude contours as the flow enters the inlet on flood tide (Figure 22) tests the accuracy of the horizontal expansion classification. Figure 22 shows a marked decrease in velocity magnitude traveling north through the inlet. The velocity magnitude decreases from a value of almost 4 ft/sec near the jetty tips to less than 2.5 ft/sec at the top of the channel bend. This sharp velocity decrease over a relatively short distance (~2,000 ft) verifies the choice of this shoal classification.

To verify the second classification (vertical expansion) requires examination of the current patterns over the channel. The velocity vectors indicate the existence of a few areas where currents enter the channel at an angle (e.g., in Figure 22, the flood currents enter the channel south of the bend at an angle to the channel axis). However, the perpendicular component of these vectors is small. Also, as currents cross into the channel, no noticeable decrease in velocity occurs. This observation suggests that the dominant mechanism causing shoaling in this area is the horizontal expansion of the channel related to the recession of the banks on either side of the channel.

The second area where the manual identified more than one possible shoal type is in Old Pass channel. In this area, one of the possible classifications was *Vertical Expansions: Cross Channel Flow*. Testing of this classification involves examination of the current patterns and velocity magnitudes in the channel vicinity. Figures 24 and 25 illustrate the inlet hydrodynamics in this area. Both figures show the currents cross the channel at almost right angles to the channel axis. In addition, the figures also illustrate the marked decrease in velocity after currents enter the channel (the shift from green to blue). Both these behaviors reinforce the selection of this classification.

A further investigation of the shoaling behavior at East Pass involves a simple treatment of sediment transport. The RMA2 model provides the velocity and water depth at each node in the finite-element mesh. From this information (together with a representative sediment size), the sediment-transport rate at each node can be calculated with an empirical sediment-transport function.

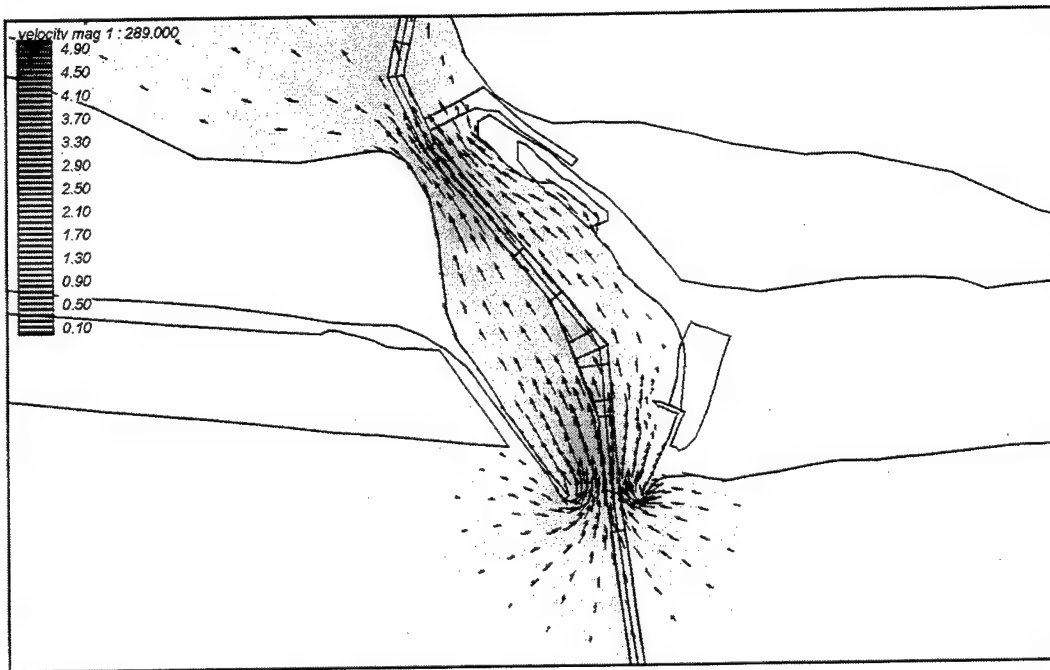


Figure 20. Velocities through East Pass Inlet on spring flood

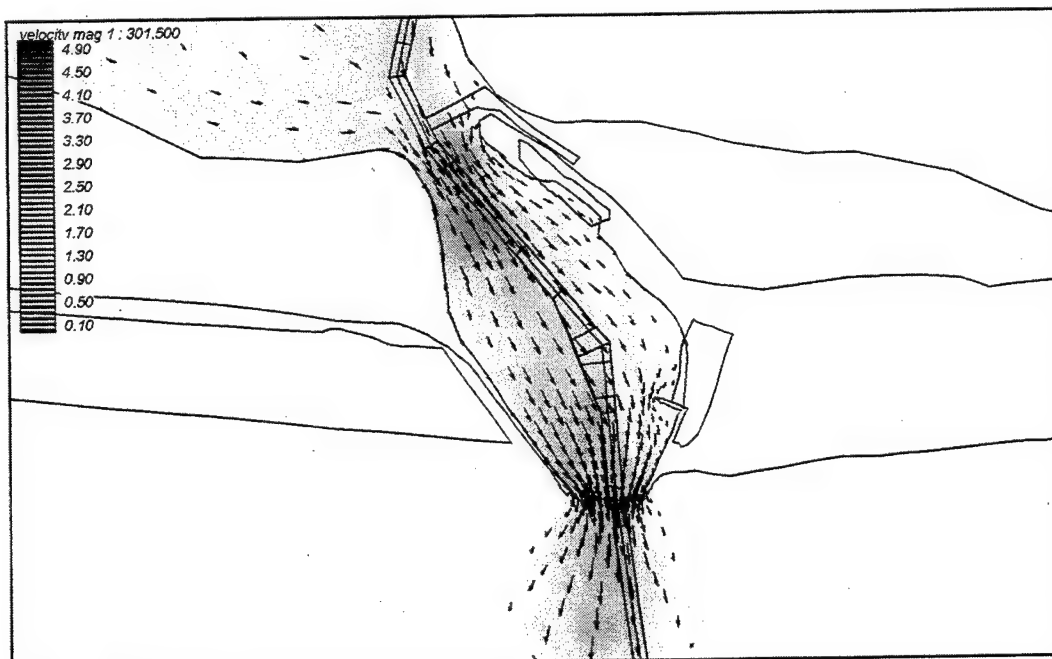


Figure 21. Velocities through East Pass Inlet on spring ebb

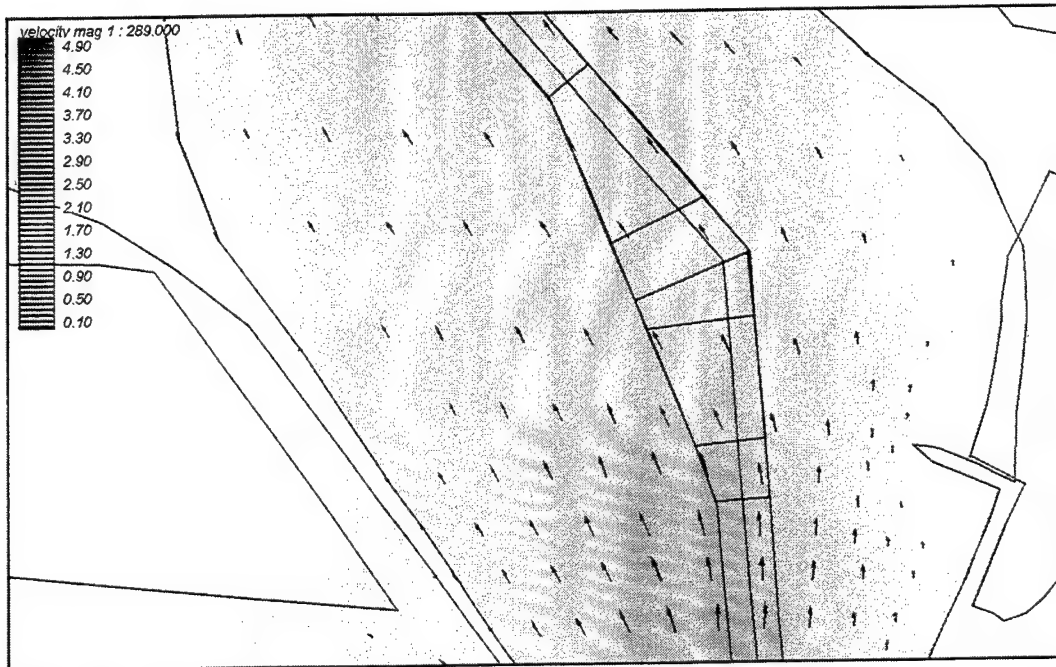


Figure 22. Velocities at channel bend on spring flood

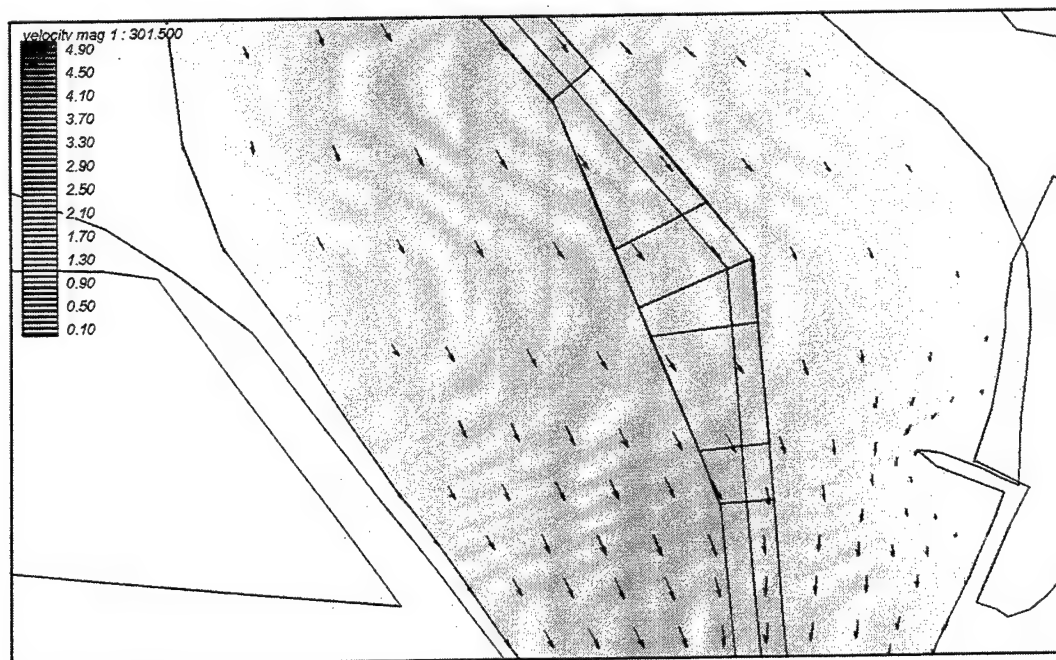


Figure 23. Velocities at channel bend on spring ebb

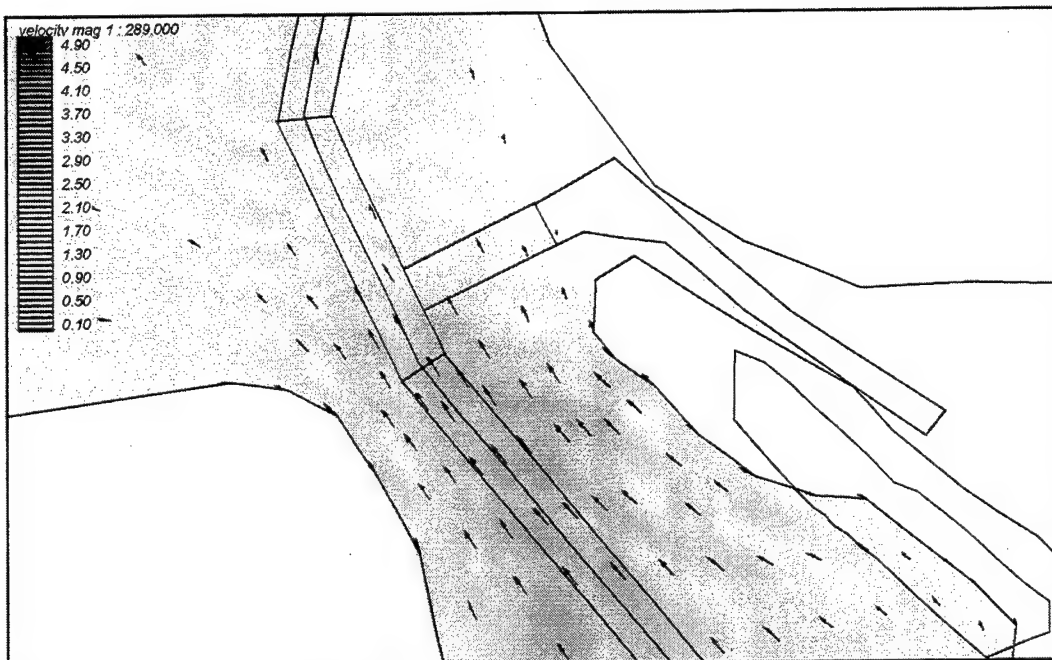


Figure 24. Velocities at Old Pass on spring flood

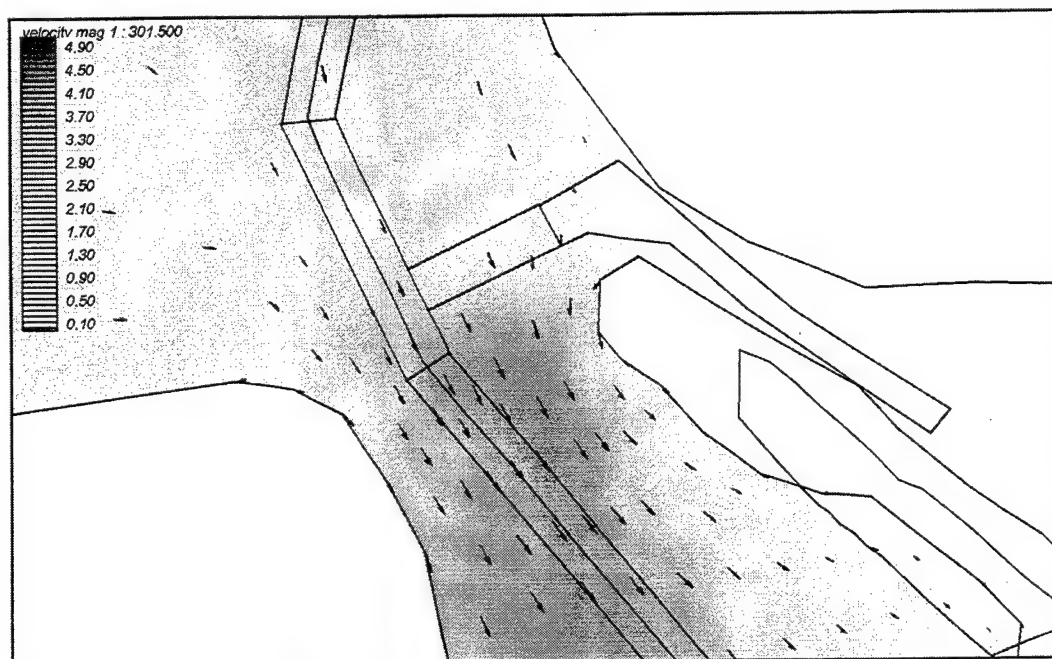


Figure 25. Velocities at Old Pass on spring ebb

The results from the simulation become input into a sediment-transport function. The function chosen for investigation was the Ackers-White (1973) formula. This total-load formula is based on dimensional analysis with empirically determined exponents. The formula takes the form

$$\frac{Q_s}{Ud} = \frac{D_{35}}{d} \left( \frac{\bar{U}}{u_*} \right)^n C_1 \left( \frac{F-A}{A} \right)^m \quad (1)$$

where

- $Q_s$  = volume of sediment transport per unit time per unit width
- $U$  = depth-averaged velocity
- $D_{35}$  = sediment diameter of the bed greater than 35 percent by weight of a representative bed sediment sample
- $d$  = water depth
- $u_*$  = shear velocity

In the equation,

$$F = \left( \frac{\bar{U}}{2.46 \ln \left( \frac{10d}{D_{35}} \right)} \right)^{l-n} \frac{\bar{u}_*^{-n}}{\left( \frac{\rho_s - \rho}{\rho} g D_{35} \right)^{1/2}} \quad (2)$$

where

- $\rho_s$  = density of the sediment
- $\rho$  = density of the fluid

Also, if the function  $D_*$  is defined as

$$D_* = \left( \frac{\rho_s - \rho}{\rho} \frac{g}{v^2} \right)^{1/3} D_{35} \quad (3)$$

where

- $v$  = kinematic viscosity

Then, for  $D_* > 60$ ,

$$\begin{aligned} n &= 0 \\ A &= 0.17 \\ m &= 1.5 \\ C_1 &= 0.025 \end{aligned} \quad (4)$$

and for  $1 < D_* < 60$ ,

$$\begin{aligned} n &= 1 - 0.243 \ln(D_*) \\ A &= 0.14 + 0.23 / \sqrt{D_*} \\ m &= 1.34 + 9.66 / D_* \\ C_1 &= \exp(2.86 \ln(D_*) - 0.434 (\ln(D_*))^2 - 8.13) \end{aligned} \quad (5)$$

Output from the hydrodynamic model supplied the velocity and depth variables. Sediment sampling suggested an estimate of 0.3 mm for  $D_{35}$ . Assumed values account for water density and viscosity.

Figures 26 through 29 show contours of sediment transport (in cfs/ft) at the shoaling hot spots. As a visual aid, vectors were overlaid on the contours. The vectors have the magnitude equal to the calculated sediment transport, but a direction equal to that of the ambient currents. The assumption is that the sediment is transported in the direction of flow (this is usually the case). As mentioned previously, the appropriate indicator of sediment deposition is the negative gradient of sediment-transport magnitude.

Figures 26 and 27 show the sediment transport during spring flood and ebb near the channel bend. They confirm the previous conclusion that shoaling in this area results from the horizontal expansion of the channel. Figure 26 illustrates how sediment is transported from south to north along the axis of the channel on flood tide. This analysis has also yielded an unexpected result. Figure 27 also exhibits the behavior associated with a horizontal channel expansion on ebb tide. Sediment is transported along the axis of the northern section of the channel. This result solidifies the selection of this classification for shoaling in this area.

Solutions to remedy this type of shoaling vary widely in cost. Shoaling from shoreline recession causes the channel to meander within the inlet throat. The least-costly solution is surveying the area regularly to designate the position of the channel by the location of the meandering thalweg. Another possible solution involves altering the geometry causing the expansion. The construction of flow-training walls would constrain the flood jet as it enters the inlet throat. This action would maintain stronger flows through the throat and hence mitigate shoaling. Notably, a "soft" solution in the same vein is to build out the shoreline on either side of the throat through the placement of dredged material. Either of these costly solutions would require a comprehensive cost/benefit analysis before implementation. One final solution is to treat the source of the sediment creating the shoal. The east jetty is presently at its sediment-storage capacity. Sediment that likely bypasses the tip of this jetty gets transported into the throat on flood tide. Once deposited, it contributes to shoaling. Extension of this jetty or mining the updrift filet would reduce the contribution from this sediment source.

Figures 28 and 29 illustrate sediment-transport contours and vectors during spring flood and ebb near Old Pass. These figures show much less variation than the previous example. Except for a small region to the west of the area during flood (Figure 28), the contours of sediment-transport magnitude are constant (solid) in almost every area within and surrounding this shoal. Near-constant sediment-transport magnitude indicates that little sediment deposits in these areas. This result suggests a need to reevaluate the classification of this shoal. Examination of the wave climate in this area helps to clarify the classification.

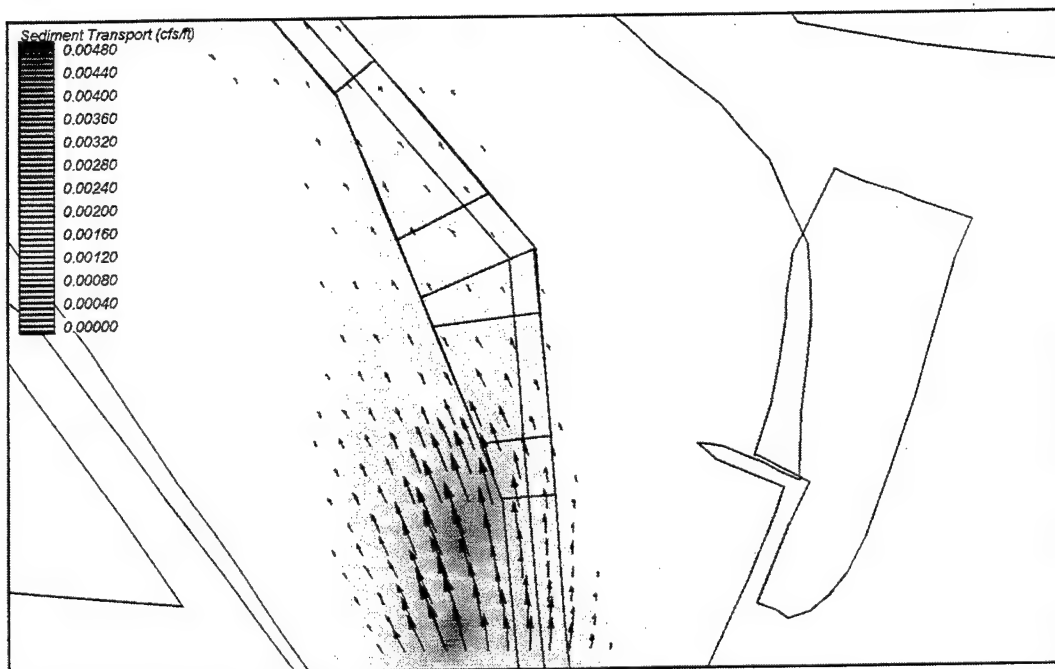


Figure 26. Sediment transport during spring flood at the channel bend

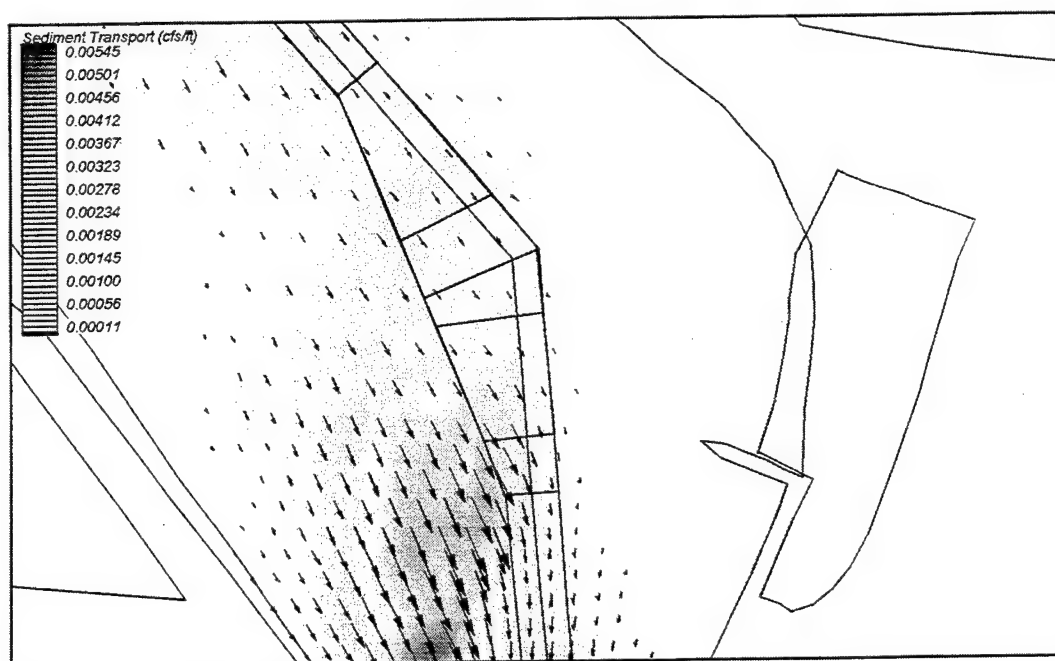


Figure 27. Sediment transport during spring ebb at the channel bend

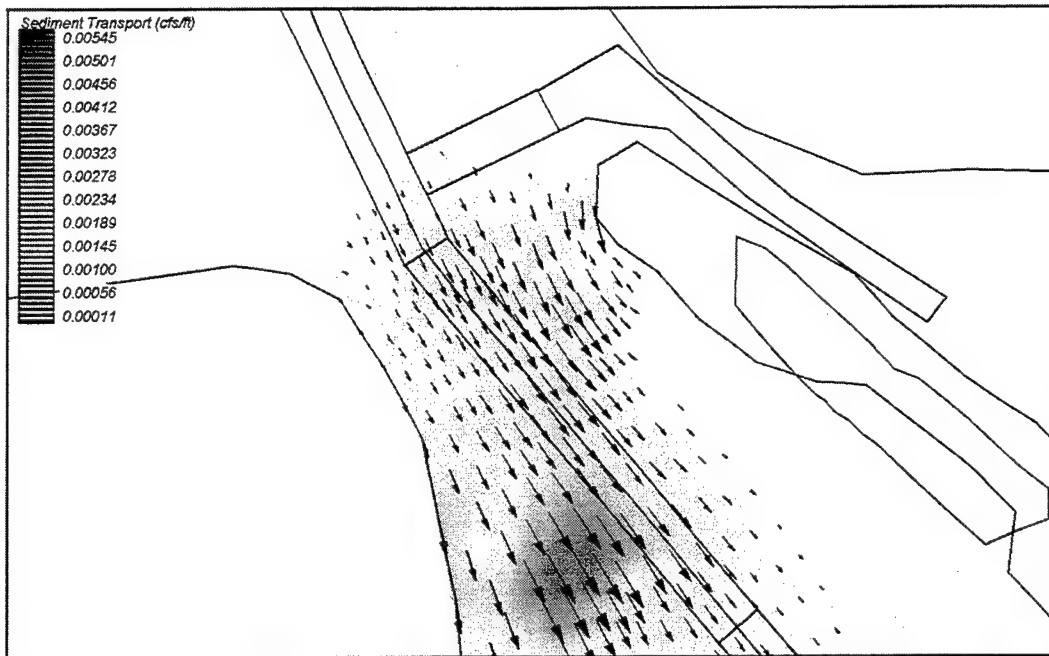


Figure 28. Sediment transport during spring flood at Old Pass

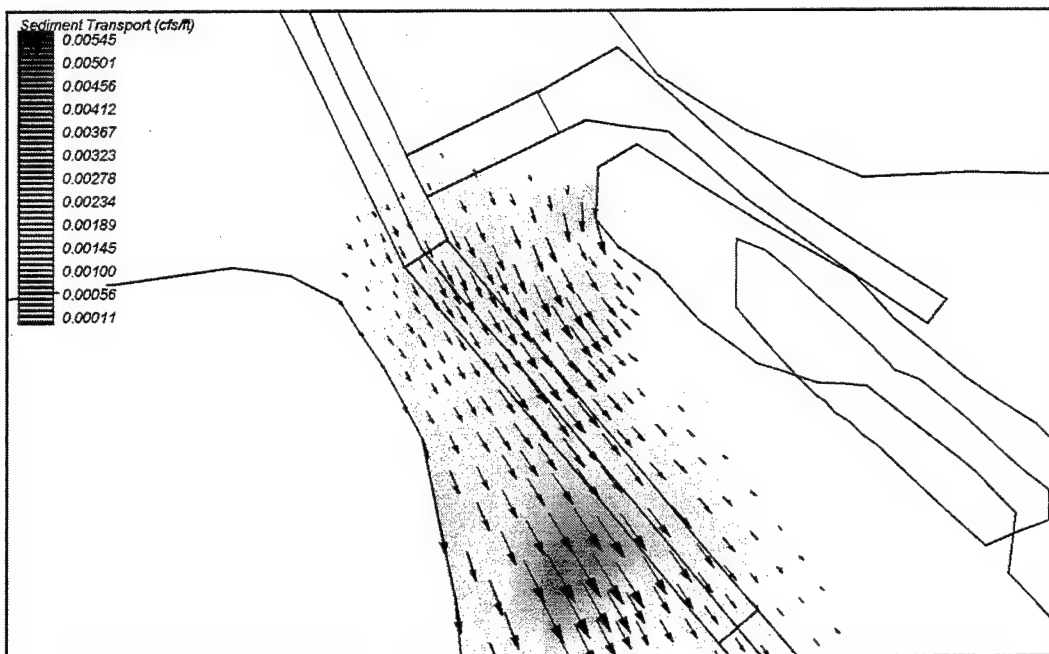


Figure 29. Sediment transport during spring ebb at Old Pass

## Wave-refraction model

The USACE-developed model RCPWave (Ebersole, Cialone, and Prater 1986) provided the means to model wave refraction at East Pass Inlet. RCPWave, a linear wave propagation model, addresses both refraction and diffraction by bottom contours. The governing equations of the model are a modified form of the "mild slope" equation for monochromatic, linear waves and the equation specifying irrotationality of the wave-phase function gradient. The model accepts as input a representative wave field of wave height, period, and direction. The program then propagates the wave towards the shore over a user-supplied bathymetry.

The identical bathymetry used for the hydrodynamic modeling was input into the wave model. Wave hindcast data from a station located approximately 9 miles due south of the inlet in 52 ft of water provided the offshore wave conditions. Wave hindcast data reduction produced representative wave conditions along 22.5-deg direction bands. The procedure for finding the wave climate in the throat required two applications of RCPWave. The first application brought the waves from deep water to the tips of the jetties. The second application, performed with a finer resolution grid, started at the jetty tips and propagated the wave through the throat. Figure 30 shows an example of both model applications. In the figure, the wave rays were drawn through interpolation of the model output.

Figure 31 is a magnified view of Figure 30 in the area of the Old Pass shoal. The figure illustrates the continued wave impact on Norriego Point despite the protection that the jetties afford. Qualitatively, the angle with which the waves strike the point and the magnitude of wave height before breaking suggest a significant amount of sediment movement or at least sediment suspension. If an adverse wave climate occurs during flood tide, currents may carry the wave-suspended sediment toward Old Pass.

A program (or "calculator") evaluating sediment-transport potential by waves was not available for this case study. This tool would help evaluate the hypothesis outlined in the preceding paragraph. Development of these types of tools is part of the DMS work unit.

Conclusions concerning Old Pass shoal are incomplete. The preceding analysis has indicated that tidal currents cross the channel at a right angle and show an accompanying deceleration. However, sediment-transport contours indicate no gradients in the area. Absence of sediment-transport gradients indicates little sediment deposition. The wave-refraction diagrams show that wave activity may play a significant role in the physical processes along the point. The synthesis of these facts prompts the hypothesis that waves suspend sediment along the shoreline and currents transport the sediment toward the pass where the sediment comes to rest. However, tools to evaluate this hypothesis are under development.

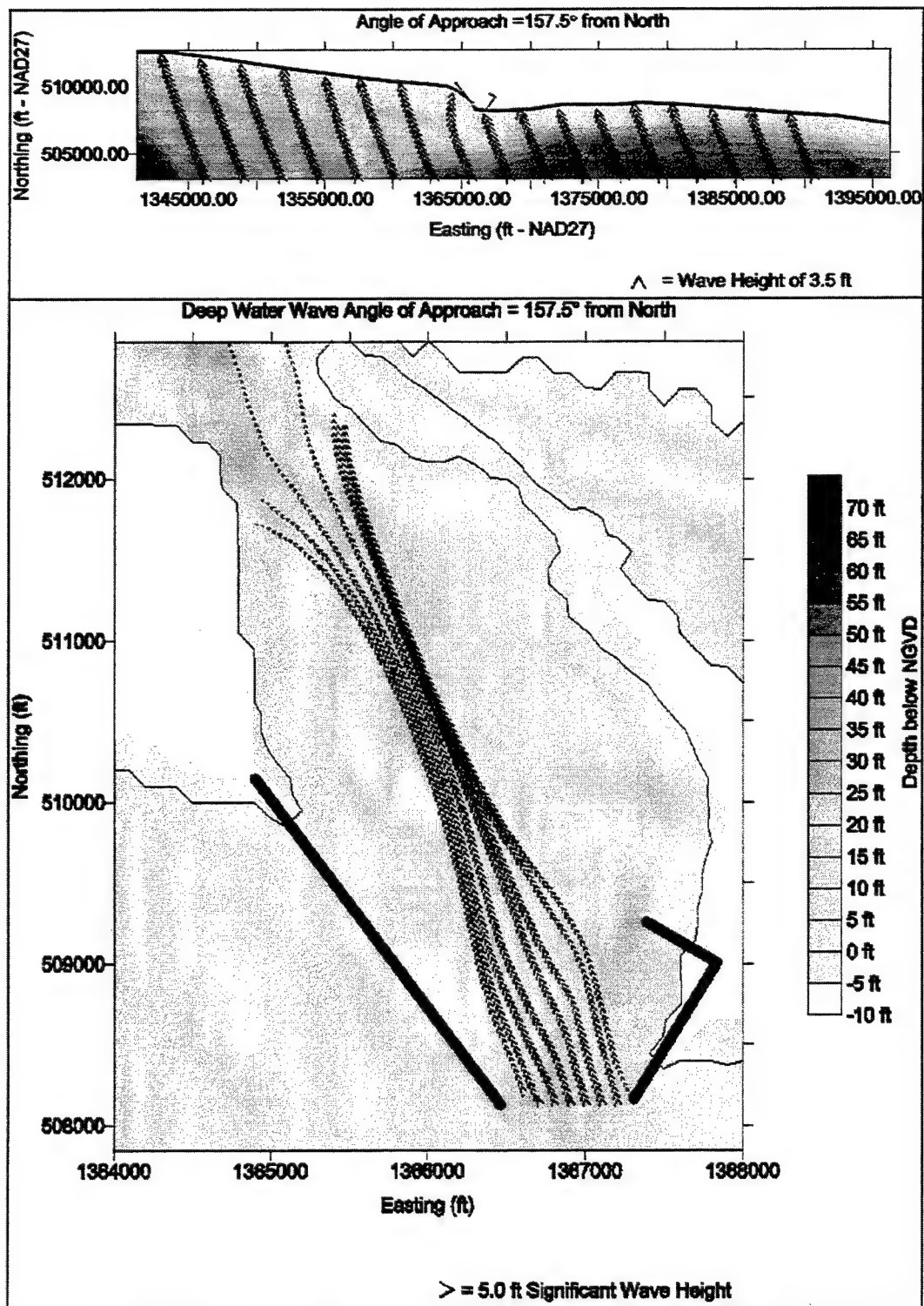


Figure 30. RCPWave wave-refraction diagrams of offshore region (above) and inlet throat (below)

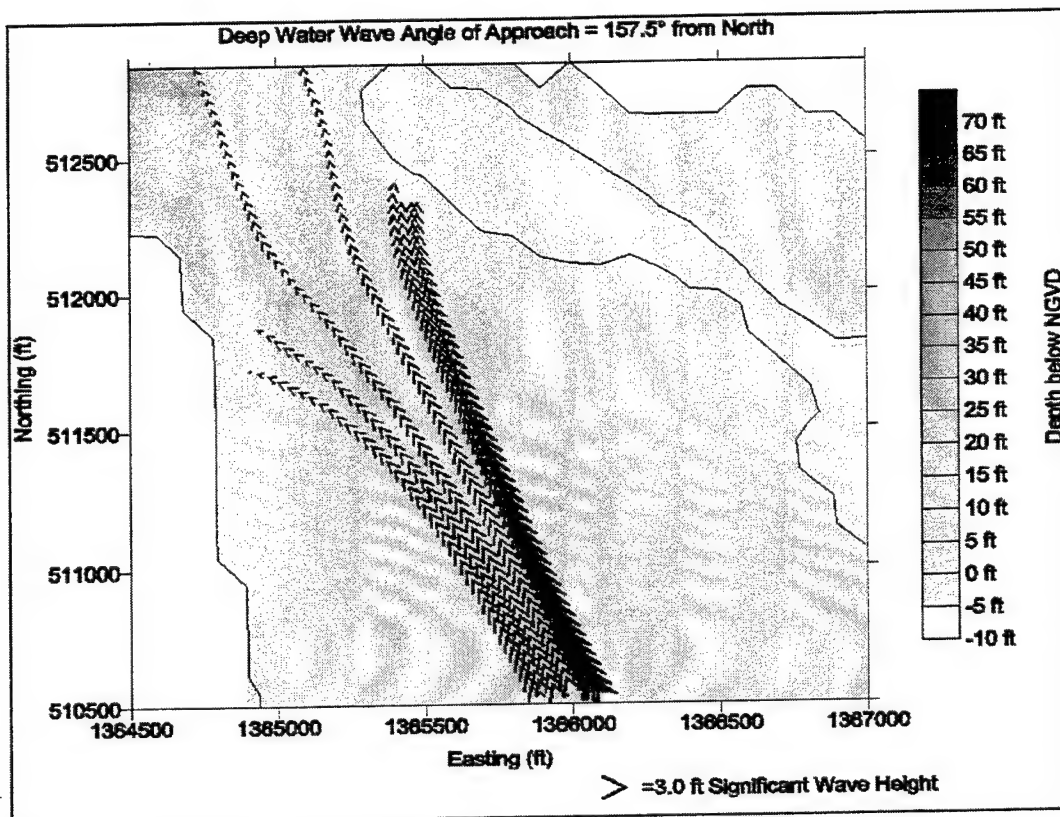


Figure 31. RCPWave wave-refraction diagram in the vicinity of Norriego Point

If the hypothesis is valid, a solution to this type of problem is to address the sediment source. The hydrodynamic analysis indicated that the currents alone were incapable of creating the shoal. Therefore, reducing the wave-suspended/transported sediment is the appropriate approach to this problem. Either a reduction in wave activity or a reduction in the actual transport may address this shoaling problem. Reducing the wave activity would involve the construction of a breakwater either outside the jetties (preventing waves from entering the throat) or directly offshore of the point. Obviously, construction within the throat is less costly than construction offshore. In addition, a breakwater aligned with the channel and close to shore would have a much smaller impact on the tidal hydraulics than would a breakwater outside the jetties.

Several actions would reduce the actual sediment transport. First, hardening the shoreline will prevent sediment movement and thus shoaling. Hardening can take the form of either a seawall or revetments. Second, the sediment may be intercepted before it reaches Old Pass. The construction of a small terminal structure at the tip of Norriego Point would trap the sediment as it moves north.

In conclusion, the application of the tools in the DMS-Analytical Toolbox have successfully clarified the classification of one of the two problem areas that fell under more than one shoaling category. The analysis of the second area provided more insight into the physical processes that create the shoal. However, the analysis also pointed out deficiencies in the toolbox that require improvement.

## 5 Summary and Recommendations

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This chapter summarizes the DMS concepts and their application to the high-shoaling rates in the channels through East Pass Inlet. The case study resulted in solutions to the shoaling problems developed through the application of each of the DMS modules: the DMS-Data Manager, the DMS-Manual, and the DMS-Analytical Toolbox. Application of these modules produced a synthesis of observations of the morphology, hydrodynamic processes, dredging records, and hydrodynamic and wave modeling results. This synthesis provides information and a framework from which to make informed decisions for taking corrective measures to address sediment shoaling at East Pass.

### Summary

The purpose of this research was to evaluate DMS concepts through its application to the excessive channel shoaling found at East Pass Inlet near Destin, Florida. The DMS methodology entails a three-pronged approach to examining shoaling problems:

- **DMS-Data Manager.** After locating all available data on a maintained channel, the engineer enters the pertinent information into the DMS-Data Manager. This GIS-based software tool displays all the information pertaining to a channel in a graphical format. This tool allows the engineer to consolidate in one program all the data, which may be contained in multiple formats, concerning a channel. The software's graphical format gives the engineer a visual picture of shoaling hot spots and their location relative to the geomorphology of the surrounding areas. The engineer can compare this picture with idealized sketches found in the DMS-Manual.
- **DMS-Manual.** This field guide of shoaling problems contains descriptions, examples, and diagrams of several shoaling classifications. The engineer matches the picture of the shoaling hot spot created with the DMS-Data Manager to the correct classification to identify the type of shoal. The description of the physical processes that create the shoal will point to possible mitigation methods.
- **DMS-Analytical Toolbox.** Often, shoaling mechanisms require a greater understanding than that provided via the DMS-Manual. The

DMS-Analytical Toolbox aids the user in those instances when the DMS-Manual identifies more than one shoaling classification. The toolbox also provides tools to investigate mitigation methods and gain a better insight into the physical processes. The DMS-Analytical Toolbox is a collection of programs and methods for accomplishing a detailed analysis of the physical processes that create the shoal. It contains programs that calculate hydrodynamics, wave climate, and sediment transport. In addition, it contains suggestions for graphical presentation of the output to help diagnose shoaling problems.

As such, the three components of the DMS aid the engineer in the diagnosis of shoaling problems and the discovery of a successful mitigation method. The East Pass Inlet case study showed the application of the DMS to three problem areas. For two of the areas, the DMS successfully identified the shoal classification and pointed to possible mitigation methods. For the third area, the application produced two possible classifications, perhaps acting together. The readily available analytical tools do not, at the present time, provide an unequivocal diagnosis. This unresolved ambiguity indicates the need for further development of the contents of the DMS-Analytical Toolbox. Despite its limitation in identifying the distinct shoaling mechanisms at the trial site, the DMS has provided insight into the possible physical processes responsible for this shoal's creation.

Application of DMS methodology led to solutions to the three shoaling problem areas found in the maintained channels through East Pass Inlet. Shoaling of the outer bar region of East Pass channel could be mitigated by conducting frequent surveys of the ebb shoal to find the lowest point in the bar and redesignating the channel to cross the shoal in that area. Shoaling in the channel-bend region, caused by horizontal expansions, may be treated in one of three ways: (a) reducing the flow expansion through construction of training walls, (b) reducing the flow expansion by building out the shoreline through dredged-material placement, or (c) preventing material from entering the inlet through lengthening the east jetty or mining the filet in the updrift beach. The tools presently available failed to produce definite conclusions concerning the shoaling in Old Pass channel. If the hypothesis in Chapter 4 concerning the shoaling in this area is valid, then recommendations would include one of the following methods: reducing wave activity through the construction of a breakwater either offshore of the jetties or parallel to the Norriego Point shoreline, hardening the Norriego Point shoreline through construction of seawalls or revetments, or preventing littoral transport into the channel by construction of a terminal groin at the tip of Norriego Point.

## **Recommendations**

This report has shown the utility of the DMS for providing a framework for formulating solutions to reduce shoaling of maintained channels. The application of the DMS to this case study has revealed a number of areas requiring further research and development. These areas are grouped by DMS component:

**DMS-Data Manager** – Research in this area should include the following:

- Developing the software as a stand-alone unit for use as a repository for all information pertaining to maintained channels regardless of intended use with the entire DMS.
- Facilitating the use/interface with the DMS-Manual and DMS-Analytical Toolbox to provide proper definition of shoals.
- Expanding and refining the software to rapidly identify shoaling problem areas.
- Helping to quantify shoals to evaluate their severity.
- Developing time frames associated with shoaling to aid in scheduling maintenance dredging.
- Providing feedback with the DMS-Analytical Toolbox to aid in calibration/validation of the analytical tools.

**DMS-Manual** – Research concerning this component should include the following:

- Investigating further shoal classifications.
- Finding relevant case studies for each classification to provide a basis of comparison.
- Finding appropriate example photographs for documenting each of the shoal classifications.

**DMS-Analytical Toolbox** – Research pertaining to this component should include the following:

- Developing back-end tools that use output from the hydrodynamic and wave-refraction models to produce definable cause and effect relationships between the physical processes and the sedimentation patterns.
- Producing diagnostic pictures of the physical processes in formats that are easily related to the encountered conditions.

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# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 1999	3. REPORT TYPE AND DATES COVERED Final report
4. TITLE AND SUBTITLE DMS: Diagnostic Modeling System; Report 2, Reduction of Sediment Shoaling of the Entrance Channel at East Pass, Florida			5. FUNDING NUMBERS
6. AUTHOR(S) Mark S. Gosselin, Kenneth R. Craig, R. Bruce Taylor			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Taylor Engineering, Inc. 9000 Cypress Green Drive Jacksonville, FL 32256			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers, Washington, DC 20314-1000 U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199			10. SPONSORING/MONITORING AGENCY REPORT NUMBER Technical Report CHL-99-19
11. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) <p>This report documents a case study at East Pass, Florida, to assess the concepts and performance of the Diagnostic Modeling System (DMS), which is presently under development. The DMS is intended to give the capability to identify, categorize, and evaluate navigation channel sediment-deposition hot spots, from which the system can be applied to identify corrective actions and perform the appropriate analysis. The level of corrective measures are expected to be within existing project authorization, and the diagnostic procedure should be capable of arriving at solutions to shoaling problems within the project dredging cycle. The system consists of three components: the DMS-Data Manager, the DMS-Manual, and the DMS-Analytical Toolbox, which are described in this report.</p> <p>The objective of the case study was to apply DMS concepts and available tools to determine the causes of shoaling in three maintained channels at East Pass Inlet and to recommend solutions to reduce the frequency and cost of dredging. The DMS evaluation led to such potential solutions, indicating the viability of the diagnostic method.</p>			
14. SUBJECT TERMS Diagnostic Modeling System Dredging East Pass Inlet, Florida Sediment deposition Shoaling			15. NUMBER OF PAGES 63
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT